THE JOURNAL

of the

TEXTILE INSTITUTE

VOL. XXVIII—1937

PROCEEDINGS AND INDEX

PI

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXVIII JANUARY, 1937 No. 1

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

ıncil Meeting : January, 1937

the regular Meeting of Council, held on Wednesday, 20th January, at ıuarters, it was decided to hold the Annual General Meeting on Wednesday, April, at 3 p.m., immediately following the monthly meeting of Council. the February issue of the *Journal* will be distributed the usual circular ing vacancies on the Council and Nomination Forms for the use of members g to propose names for election to fill these vacancies.

annual Mather lecture will again be delivered during the Institute Con-ce—at Southport, in June next—and the Council learnt with satisfaction Sir Harold Hartley, Vice-President of the L.M. & S. Railway Co., has ɔted invitation to contribute this lecture. It is hoped to be able to send a ninary notice to all members by the end of February, giving further par-ırs of the Conference arrangements.

ır some time representatives of scientific organisations, analogous to this tute, have been exploring the possibilities of co-ordinating the efforts and ests of such bodies in the general subject of testing materials. The Institute been represented by Messrs. J. H. Lester and W. Kershaw, either of whom ɔoth have attended all the meetings of the provisional Committee. On ıary 12th, this Committee met in London and decided to establish a ɴanent "Joint Committee on Materials and their Testing": the terms of rence being:—

o act as the British National Organisation in matters relating to materials and their testing.

report on the whole subject, giving the Objects of the Committee and the s adopted at the first meeting, was submitted by the Institute's esentatives. It was decided to co-operate in this work and pay the first al subscription. The Council re-appointed its representatives: one to ıd if the other was unable to do so. Dr. H. J. Gough, of the National Physical ratory, is chairman of the Joint Committee.

ɴbers' List and Cards

. has been decided to issue a copy of the Members' List for 1937 to all members it is hoped to do so with the March or April issues of the *Journal*. That s list may be as up to date and accurate as possible, members are asked to ıd changes of address, and all particulars to be included in connection with .eir names to the General Secretary as soon as possible after the appearance f this note. It is also to be noted that it has been decided to discontinue the .embership card usually sent out on receipt of the annual subscription.

Library Facilities

In response to a request for the Institute's library to be opened at night and/or on Saturday afternoon, these facilities were made available for the last six months of 1936. The attendance has been so small, less than an average of two, that the Library Committee has been obliged to discontinue the special opening of the Library. On the other hand a steadily increasing use of the books and periodicals available can be recorded. It is apparent, however, that a large proportion of members do not yet realise that the Library contents can be borrowed by post and it is hoped that the recent issue of a library catalogue to all members will do much to remove this misunderstanding.

Obituary : Dr. R. S. Willows

It is with regret that we record the death of Dr. R. S. Willows. Some of his work has appeared in the Transactions section of this *Journal*, and he was for a time Chairman of the Publications Committee. A graduate of Nottingham University College, he conducted research work under Professor J. J. Thomson, at Cambridge. Later, for work in physics, he obtained his Doctorate and was appointed to the Battersea Polytechnic. From there he went as Head of the Physics Department of the Sir John Cass Technical Institute. In 1918 he took up an appointment with Messrs. Tootal, Broadhurst Lee, of Manchester. He became head of this firm's Research Department and later was elected to the Board of Directors. His health was latterly not good but his death came rather suddenly. His passing deprives the Textile Industry of the services of a valued worker in the scientific field.

Leverhulme Research Fellowship, 1937

Application is invited for (i) Fellowships and (ii) Grants in aid of research. The Fellowships are intended primarily to provide for senior workers a period of freedom from routine duties during which they may undertake or complete researches which are being delayed through the pressure of other work. The Grants are intended to provide for senior workers, who may not require release from their ordinary duties, such assistance as may be necessary to enable them to expedite or complete their work. Neither Fellowships nor Grants are awarded to graduates doing research with the object of obtaining higher degrees. Applicants must be British-born and normally resident in the United Kingdom. In exceptional circumstances the Trustees may waive the condition as to residence.

The duration of the grants will not normally extend over less than three months or more than two years, and the amount will depend on the nature of the research and the circumstances of the applicant. Any subject which may add to human knowledge may be proposed for a Fellowship, but preference is given to subjects in which other provision for research is inadequate.

Forms of application may be obtained from the Secretary, Dr. L. Haden Guest, Leverhulme Research Fellowships, Union House, St. Martins-le-Grand, London, E.C.1. Applications must be received on or before 1st March, 1937. Awards will be announced in July, and the Fellowships or Grants will date from September 1st, 1937.

Employment Register

The following announcements are taken from entries in our Register of members whose services are on offer. Employers may obtain full particulars on application :—

No. 152—A.T.I. requires position as Assistant Manager, Manager or Works Chemist to Woollen manufacturers. B.Sc. in Applied Chemistry. Prepared to go abroad. Leeds University Diploma in Dyeing. Age, 34 years.

No. 153—Desires position as Textile Technologist or Technical Advisor to Private Firm or Public Body. 15 years' experience in Hosiery Trade. 5 years' experience at Public Testing House. Knowledge of Costing, Factory Management, Past Examiner. A.T.I. Fellow of Royal Microscopical Society. Age, 34 years.

TEXTILE INSTITUTE DIPLOMAS

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (November issue of this *Journal*) :—

FELLOWSHIP

HAYES, John Edward (Bolton).

ASSOCIATESHIP

DAWSON, Fred (Manchester).
DAWSON, Herbert (Preston).
STRAATMAN, Jan Frederik (Manchester).
THOMPSON, Alan (Chaddesden, near Derby).

Institute Membership

At the January meeting of Council, the following were elected to Membership of the Institute :—

Ordinary.

W. C. Fairweather, M.A. (Glas.), 18, St. Ann Street, Manchester (Chartered Patent Agent).

A. Gaskell, 20, Nicholson Avenue, Macclesfield (Assistant Throwing Mill Manager).

C. A. Hatton, M.Sc.Tech., A.I.C., 13, Aldermary Road, Chorlton-cum-Hardy, Manchester (Chemist).

F. Partington, A.M.C.T., Frith Knoll, Chevin Road, Belper, Derbyshire (Technical Assistant to General Manager, W. G. & J. Strutt, Ltd.).

A. Perkins, M.A. (Cantab.), The Technical College, Norwich (Head of Boot and Shoe Dept.).

F. V. Read, Broomefield House, Blakedown, near Kidderminster (Assistant to General Manager, Carpet Trades Ltd., Mill Street, Kidderminster).

M. G. Sarkar, B.Sc. (Calcutta), Khagra P.O., Murshidabad Dt., Bengal, India (Weaving Overlooker, Asharwa Mills, Ahmedabad).

Lancashire Section

At a joint meeting of the Lancashire Section of the Textile Institute, the Manchester College of Technology, Textile Society and the British Association of Managers of Textile Works on December 11th, 1936, at the College of Technology, Mr. Ronald Dunkerly delivered a lecture on "Modern Management.

Mr. Dunkerley explained that the need for " management " appeared in small as well as in large businesses, though it was probably the absence of the personal touch in the latter that had led to the development of the subject and to the formulation of general principles applicable to all types of business. The old view that management can best be carried out by personal observation and experience is nowadays somewhat suspect. The existence of price fixing, joint marketing and other similar organisations demands from those entrusted with management a much wider review of conditions than was hitherto necessary.

The idea of securing " manufacturing load factor " without full consideration of the problems of distribution has been exploded along with such notions as the reduction of costs of production through the cutting of rates of wages, or by reducing the quality of the articles. The provision of up-to-date machinery kept in perfect order, efficient layout, proper auxiliary equipment for lifting and transport, correct lighting, heating and ventilation are now recognised as very important factors contributing to economy.

The detailed statistical analysis of sales permits the management to determine whether any particular line is remunerative or not and to conduct a thorough

examination before an unremunerative line is modified or withdrawn. The comprehensive view of a good manager will counteract the inevitable loss of true perspective which follows on concentration on masses of detail. The fullest use must be made of "market research" and the statistical information issued by Government Departments and centralised information bureaux. Purchasing is equal in importance to selling, particularly if the carrying of unnecessary stocks is to be avoided. A rational system of budgeting can help very materially towards such a desirable end.

The avoidance of labour misfits is beginning to receive the attention for which it calls so loudly. Technical education and training must therefore be closely watched and managements must be ready to put their ideas, experience and requirements before educational authorities for consideration. There are well known instances where such requirements are so specialised that the employers have no alternative to the actual provision of the necessary educational facilities. Welfare work would appear in many cases to be a very profitable investment and though profit-sharing schemes may often be viewed by workpeople with suspicion it does not follow that this will always be the case.

Emphasis was laid upon the value of so-called "time and motion" studies, particularly when these are carried out tactfully and preferably with the co-operation of the workers.

Research and development work would appear at first sight to be possible only in large concerns. Yet much benefit can be derived from membership of a Research Association, particularly if a trained scientist is employed in the interpretation and application of the research association's publications and recommendations.

In conclusion it was stated that management is a far more complicated problem to-day than ever it was previously and that modern competition demands the close study of every possible aid to efficiency. It was hoped that the treatment of the subject would stimulate those who were endeavouring to increase the success of their undertakings.

Midlands Section

On the evening of 10th November, a party consisting of nearly forty members of the Midlands Section paid a visit to the new and excellently-equipped Research Laboratories of the London Midland and Scottish Railway Co. at Derby.

Under the guidance of Mr. W. Pritchard, A.T.I., and his staff the members were escorted round the various Testing Departments. Not only the section devoted to Textiles but the Metallurgical Sections were also visited, and the various testing processes carefully demonstrated and explained.

Specimens of the very extensive range of textiles as used by the Company, with such variations as from cleaning material to uniform cloth and from axle box pads to the finest of furnishing fabrics were displayed to the members, and the very rigid tests to which they are all subjected—e.g., for fastness of colour, wearing propensities, tensile strength of the individual fibres, etc.—were also demonstrated.

At the conclusion of this most interesting and instructive evening, Dr. E. Wildt expressed the appreciation and thanks of the Midlands Section to the London Midland and Scottish Railway Co. for their courtesy in so kindly allowing them to make this visit, and also to Mr. Pritchard and his colleagues for the time and trouble devoted to it.

Irish Section

The first meeting of the Session was held in the College of Technology, Belfast, on Thursday, 10th December, 1936, when a paper entitled "Some Effects of Warp Tensions during Weaving" was contributed by Mr. H. Boffey, B.Sc. of The Linen Industry Research Association. The Chair was occupied by Professor

F. Bradbury, B.Sc., F.T.I., and there was a good attendance of members and friends.

The Lecturer observed that the tension in the warp yarn during weaving affected both the structure and the appearance of the cloth apart from its bearing upon the warp end-breakages. In this discussion he did not propose to deal with efficiency of production.

Good " cover " on plain cloth was usually obtained by " troughing " the shed, that was, producing at the beat-up a comparatively tight bottom shed and slack top shed. The constant interchange in each warp end of alternately high and low tension allowed these ends to spread uniformly over the weft and so avoid " reediness." In some plain cloths, there was a tendency on the part of the warp to form groups of four ends. This was undoubtedly connected with the existence in the warp of a tension " pattern " repeating on four ends.

Corresponding effects might also occur which were associated with irregular weft spacing. A weft pick was more efficiently beaten home into the fell of the cloth when the warp was tight than when it was slack. This showed as a grouping of the weft in pairs rather like the spacing of warp in a reedy cloth when the whole warp tension varied between alternate pick cycles. A striking example of it sometimes occurred in weaving damask cloths with a pattern consisting mainly of a large square satin band. The normal pick spacing present in the centre or ground altered when going on to the cross-band and again when leaving the band and the general result was to weave into the cross-border more picks per inch than were anticipated, the usual remedy being to insert more cards for the border.

Mr. Boffey proceeded to describe the case which is treated at length in the transactions section of the present issue.*

Another example of the importance of individual warp tension was one in which commercial use was made of a systematic control of the latter to produce interesting patterns on otherwise plain cloths. A mechanism consisting of three horizontal bars, one of which could be vertically oscillated about an axis parallel to the other two, was attached to the back of a plain loom between the back shell and lease rods. The warp yarn was divided in a certain manner round the oscillating bar and all passed finally between the other two bars. The arrangement thus allowed of the warps passing over the oscillating bar to be tightened and those passing under to be slackened whenever the bar was moved upwards from a central position ; the reverse effects took place when the bar was moved downwards. This tightening and slackening of warp ends could be carried out in complete cycles having a definite number of picks per cycle and the result in the cloth was a series of wavy wefts continually altering as regards depth and direction of wave and together forming an attractive pattern on the fabric. This was the general basic principle. A great variety of effects could be obtained by varying the method of dividing up the warps for passage over and under the oscillating bar, altering the number of picks per tension cycle, making the motion of the mechanism systematically intermittent, employing coloured weft, and so on. Many of these possibilities were illustrated in a considerable range of samples shown by the author at the end of the lecture.

An interesting discussion followed and on the proposition of Mr. Jackson, seconded by Mr. Silcock, a hearty vote of thanks to Mr. Boffey was passed by acclamation.

REVIEWS

Textile Prüfungen : Welche einfachen textilen Prüfungen lassen sich ohne Mikroskop und ohne besondere Apparaturen leicht ausfuhren? By. E. Wagner. Published by Ziemsen Verlag, Wittenberg, Halle. Price, 2 R.M.

In this small booklet there are tabulated and explained a number of simple

*" The Cause and Avoidance of Warp Shadow Stripes in Damask Cloths." This issue pages T1-T12.

tests by which yarn and cloth characteristics may be determined without the use of a microscope or other elaborate apparatus. Although much of the information thus presented is elementary, it is also practical and useful. The first section treats of the reaction to burning of the various fibres and yarns, and outlines a number of tests by which cotton yarns may be distinguished from flax, pure silk from mercerised cotton, pure silk from wool, etc. In dealing with methods of distinguishing between the most important bast fibres, and between the various types of artficial silk, a certain amount of apparatus, in the form of flasks, acids, means of heating, etc. is required. Dr. Wagner states, however, that he has outlined only such tests as he believes them to be more speedy than examination by the microscope.

The second section of the booklet, dealing with fabrics, outlines some quick methods of determining thickness, handle, weight, strength, wear, density, finish, etc. Simple tests are also given for fastness of dyed fabrics and for waterproofed fabrics. Many of these tests are purely "subjective," such as those for "handle" and strength; others, such as testing for weight, are more definite. On the whole, however, to those whose work necessitates a knowledge of yarns and fabrics and who lack commercial or technical experience of the trade, Dr. Wagner's suggestions should prove of considerable value. W.

Processing and Finishing Cottons. By James F. Monaghan. Published by Frank P. Bennet & Co., Inc., Boston, Mass. (2 vols., 1,008 pp.). Price, $12.00.

According to the author this work "is an accumulation of the results of years of experience and study in the finishing plants in this country (U.S.A.), and the results of thoughts formulated after the writer's experience during 1918-1919 as Chairman of the Textile Board on the American Commission to Negotiate Peace at Paris, and charged with the survey of damage to textile plants in the devastated areas of France and Belgium."

It is rather a journalistic account of the industry and, as such, of more use to the commercial section than to technical men, though the latter will also find items of interest.

After a chapter on the reasons for processing cotton, three chapters are devoted to a brief survey of the subject. The next four chapters are a discussion of grey cloth. Then five chapters deal in a very elementary way with the chemistry of substances used in finishing. Bleaching takes up eleven chapters, dyeing eight and printing four chapters. Most of the second volume is occupied with starching, mercerisation and other finishes.

The book contains a mass of information and is well illustrated with 129 figures in the text, but the author's personal views which are too frequently obtruded into the descriptions will not meet with universal approval. For instance on page 170 he writes :—

"The plants are the best research laboratories to be found. Everything investigated in them is practically applicable to the industry, and the accomplishments from the investigations must be right; otherwise the plants would cease to operate. Through the history of the industry our plants have been served by men born to the job; men with a background covering several generations of ancestry in the same field, who are just as far-sighted and keen of thought and idea as any other group of men who, as theorists, could fill a page with chemical reactions. These men develop ideas of their own and put them into paying operation. They know nothing of chemical technique, but it is a pretty well recognised fact that if our best theorists met one of them on the wash room floor in a pertinent discussion, theory would learn something it had never heard of before, and would depart to make its new deductions."

Fine rhetoric, but in Europe at any rate the doctrine of the infallibility of the practical man is gradually being debunked. Discussions are daily taking place in the workshops between theorists and practical men to their mutual advantage. It is true that the industry contains very many practical men with profound insight into processes and it is also true that there are ignorant "scientists"; but the converse is equally true. Sometimes the only difference between members of the two classes of workers is that the practical man will believe no theories but his own, whereas the theorist has not sufficient faith even in his own theory. The fact remains however that practice has been enriched in recent years by knowledge gained in science laboratories and if the author had included some

account of the valuable researches which have been made during the past two decades on textile processes by first class scientists he would have produced a better book. R.G.

Vegetable Oils and Oil Seeds. A Summary of Figures of Production and Trade relating to Cottonseed, Linseed, Rapeseed, Sesame Seed, Soya Beans, Ground Nuts, Copra, Palm Kernels, Palm Oil and Olive Oil. Compiled in the Intelligence Branch of the Imperial Economic Committee. H.M.S.O. Price 2/6 net.

The Imperial Economic Committee's compilation surveys the production and distribution of vegetable oils and oilseeds throughout the world over a period of nine years. Tables are given showing acreage under cultivation, world production (Empire countries shown separately) exports and imports and in some cases price movements. From the textile point of view the data relating to olive oil are the most interesting. Production is confined to the Mediterranean countries. Spain has been the largest producers of oil and the United States and France have been the largest consumers. The wool combing industry is a relatively small but important consumer. The increase in price consequent upon the present upheaval in Spain may have far reaching results. T.

Book of A. S. T. M. Standards, 1936. (Issued Triennially.) Part II. Non-metallic materials. Published by the American Society for Testing Materials, 260, S. Broad Street, Philadelphia, P. A. Price 7 dollars 50 cents.

In the textile section of this work are a number of new standards adopted in the year 1936. T.

The British Launderers' Year Book. Published by the Institution of British Launderers, Ltd., London.

The British Launderers' Year Book, 1936-1937, is a handsomely produced volume. It cannot fail to be of great value to the members of the organisation which has recently changed its name to the " Institution of British Launderers Ltd." The Editor, in his brief introduction, draws attention to the tremendous expansion of the industry during recent years. The volume is a veritable mine of useful information. The well-displayed List of Contents is a good feature, for the value of such material is doubled by virtue of its being immediately available when required. The completeness of the matter, together with its concise arrangement, must inspire the confidence of the user of the book.

In a perusal of this Year Book one is impressed by the advertisements. The compilers fully realise that the advertisements of manufacturers, etc., are of great assistance to their members. Their distribution through the book—the index facilitates ready reference—is preferable to their segregation in wads at the beginning and end of the volume. To the buyers' guide frequent reference will obviously be made. It is difficult to imagine that any member of the Institution of British Launderers Ltd. can be other than delighted with this official year book. T.

Complimentary Luncheon to Mr. F. W. Barwick, F.T.I.

The Textile Institute naturally records with pleasure the occasion of the entertainment to luncheon on December 22nd, 1936, of one of its foundation members, Mr. F. W. Barwick, F.T.I., in celebration of his completion of twenty-five years of service as Director of the Manchester Chamber of Commerce Testing House and Laboratory.

Mr. Clucas spoke on behalf of the directors, giving a brief account of the work of the Testing House and the tremendous growth of its activities during the period of Mr. Barwick's service. The examination of 45,000 samples in the year 1936 is no mean achievement.

Mr Clucas proceeded :—

" I have referred so far to the Testing House rather than to our guest of honour to-day, mainly because I know he is a man whose wish it will always be to remain personally in the background and to allow any credit that is going to be attached to the institution he has served with so much skill and devotion rather than to himself. Mr. Barwick is an example of the unostentatious attitude of the

scientist towards his calling, and all of us like him better on that account. But to-day we are celebrating an anniversary which is personal to Mr. Barwick, and for once in a way he must allow me to be a little personal about him. Mr. Barwick began his career in the laboratories of the Imperial Institute in London. At the time when a vacancy arose in our Testing House he had just been appointed to take charge of a new Testing House which the Corporation of Belfast had decided to set up. He came to us, therefore, from London but via Belfast. That short period in Belfast in 1910 and 1911 takes us back to the days when Carson and Galloper Smith were at the height of their fame in the great political battles on the question of Home Rule.

" But Mr. Barwick's life work has been that of our Testing House, and with him everything else, even his own leisure and pleasure, has come very much second. Had he been of a different mould there is no question but that he would have been seized upon by many who have recognized his exceptional talents and induced to figure in many other activities. Being the man he is, people who have desired to persuade him to devote himself to matters out of the Testing House have had to put up a very good case. The most successful amongst these have been the Council of the Textile Institute. Mr. Barwick realised how important to the future of the textile industry the question of technical education amongst the young people entering the industry was, and he acquiesced in the appeals made to him to lend a hand with the work of the Textile Institute in this connection. As in everything else he has been in this connection also the personification of modesty, but he has not been able to restrain his friends and admirers from giving tangible expression to the appreciation of his notable work. The Textile Institute has recently made him a Vice-President, after giving him the Medal of the Institute four years ago, in the words of the gift, ' for distinguished services to the industry.' He is Chairman of various committees of the Institute, and is to-day Chairman of a very interesting committee jointly set up by the Board of Education and the Textile Institute in connection with the scheme for National Certificates in Textiles.

" Within the past year Mr. Barwick has succeeded Mr. Harold Lee of the Tootal Broadhurst Lee Company as Chairman of the Textile sub-committee of the Governing Body of the Manchester College of Technology, a tribute to his eminence and authority in his own field of which we must all rejoice to hear. Such tributes are far from rare in Mr. Barwick's experience. Many bodies have acknowledged his help and advice in technical matters. One of his treasures at home, as I happen to know, is a strikingly elaborate Presentation Copy of something at least half of you here present will know nothing about. I refer to the Pharmaceutical Codex. For the sake of the ignorant, I may say this is a standard work of reference for pharmacists in which is laid down what must be and by inference what must not be in the practice of their science. It is issued as the professional bible by the Pharmaceutical Society of Great Britain and is revised every so often but not too often for it is an immense labour. Mr. Barwick was prevailed upon to associate himself with the last revision which took two years, and took special responsibility for sections in which surgical dressings were involved.

" No one could say of our friend Barwick—and I drop the ' Mr.' when I come to these personal remarks—that with his friendships or in business he would dash in where angels fear to tread. Quietness and a certain reserve are characteristic of him, so that he is not perhaps the easiest of men to get to know well enough to speak about. But when you do get to know him, as I have done in my office as Chairman of the Testing House Committee, you are deeply impressed by his profound loyalty to the institution he serves, by his single-mindedness, by his great industry, and by his monumental reliability. It has been fortunate indeed for the Chamber to have such a man at the head of the Testing House for so long, and we rejoice to congratulate him on his jubilee, wishing him health and strength to continue his invaluable work for the Chamber for many years to come."

THE MEASUREMENT OF YARN TENSION ON SPINNING MACHINES

By Prof. Dr. Ing. habil. F. Oertel

The development of machines and processes has made especially rapid of late in all branches of industry. On inquiry as to which part of the engineer's work is chiefly concerned therein, it becomes evident that technical measurements must be regarded at present as the real pacemakers in developments in all industrial fields. Exact measurement permits, in the first place, of the systematic examination of the problems in the manufacturing processes of any particular branch of industry. It leads to the discovery of shortcomings in manufacture and to the adoption of improvements. When testing such improvements, it will serve for assessing the value and the degree of the

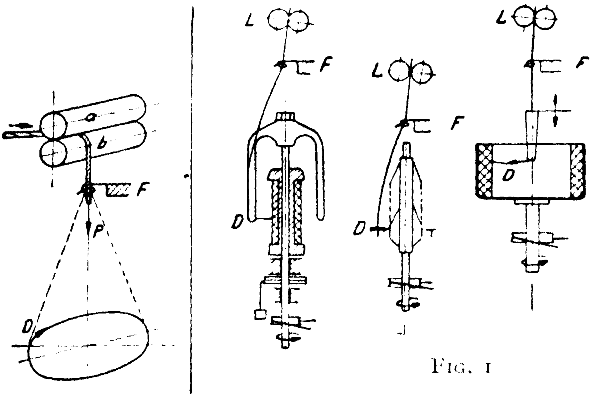


Fig. 1

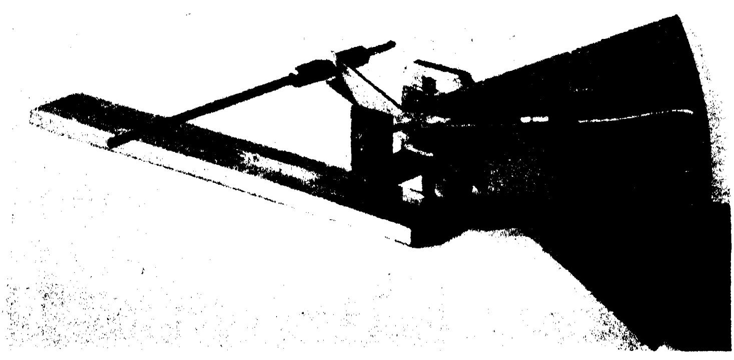


Fig. 2

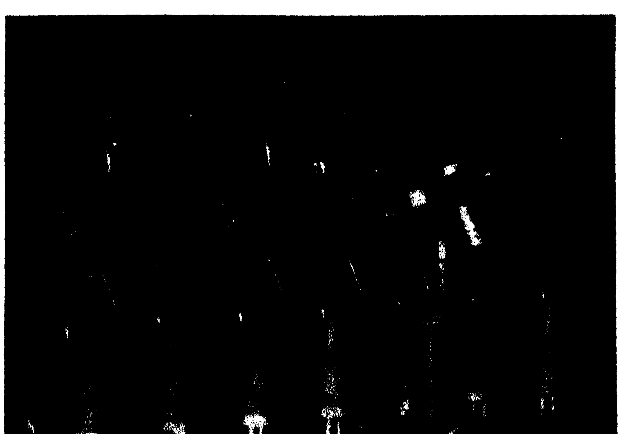


Fig. 3

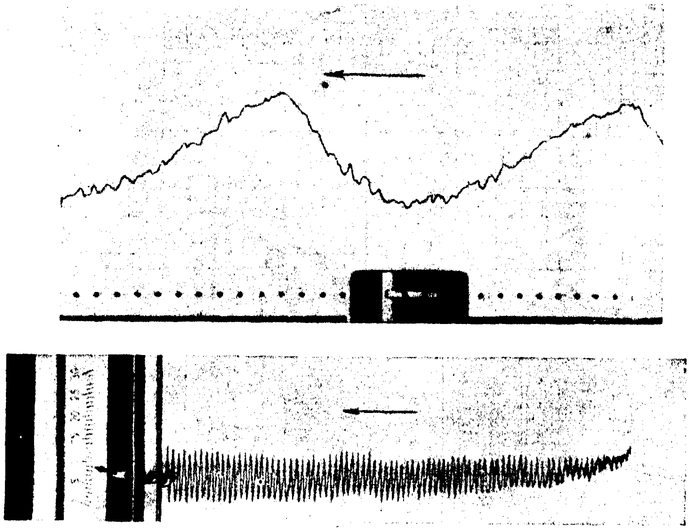
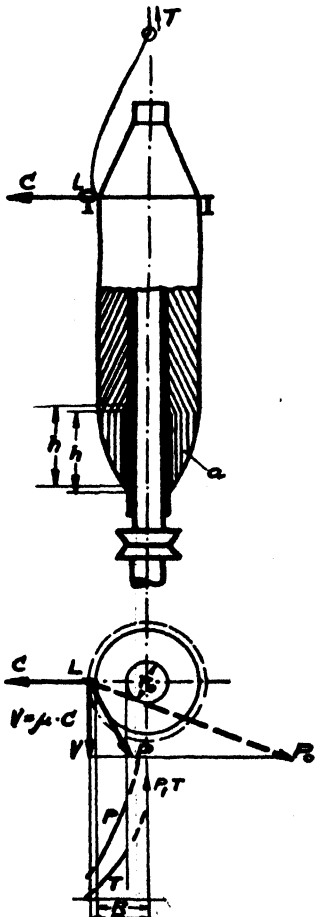


FIG. 4



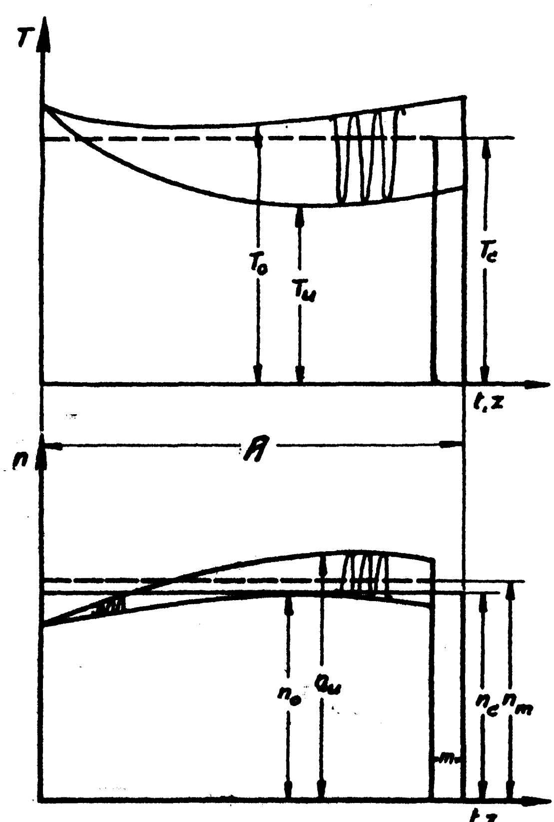


FIG. 5

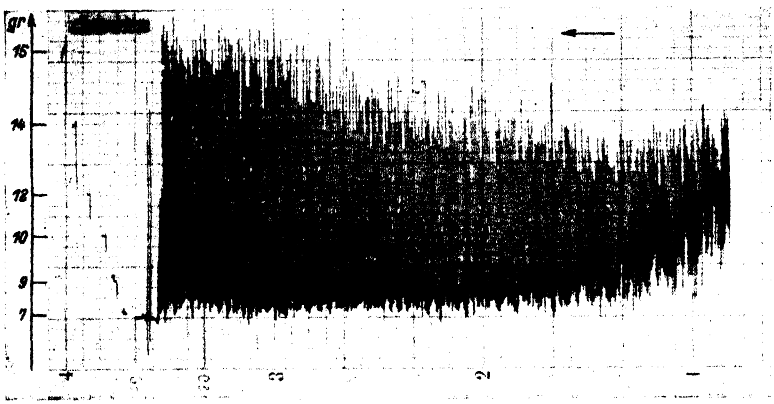


FIG. 6

improvement introduced. It is the general importance of exact measurement, and especially electrical measurement in industrial progress that it is desired now to demonstrate in the special field of spinning technique, and to show the succession of stages of application.

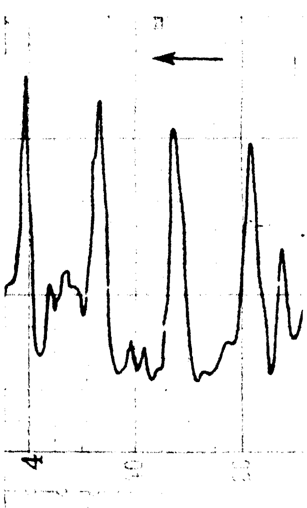
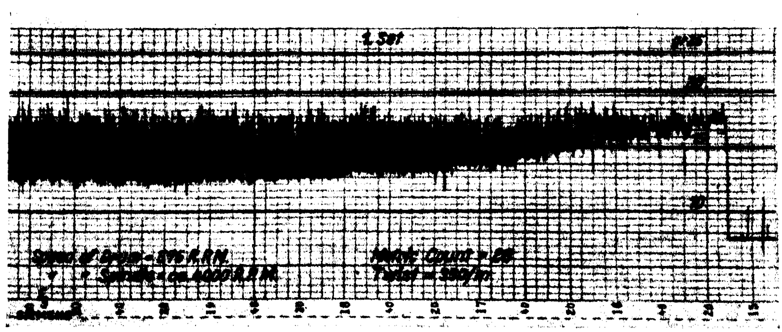


FIG. 6

Yarn tension in continuous spinning affects very considerably the producton and quality of the yarn, and is for this reason fully deserving of careful study by means of exact measurement. Fig. 1 shows three representative devices for continuous spinning, namely, the flyer spindle, the ring spindle and the pot spindle, the last being well known in the manufacture of artificial silk. With the self-acting mule, operating intermittently, it is not here proposed to deal.

Yarn tension arises from the centrifugal and frictional forces on the yarn. The centrifugal forces cause the yarn to take the form of a balloon. In the case of the ring spindle the traveller is also involved. Yarn tension depends on the diameter of that part of the bobbin on to which the yarn is being wound. As is well known, the distribution of tension, twist and strength in the yarn up to the grip of the delivery rollers is impeded by friction in the thread guide. Above the guide the yarn is only slightly twisted, not very

FIG. 7



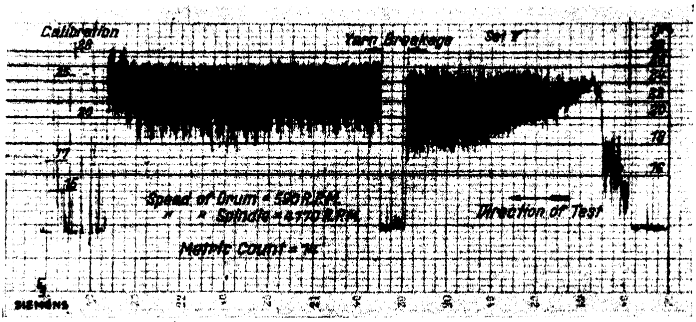


FIG. 7

strong, and therefore especially subject to breakage. Hence, this is the position in which the yarn in process of manufacture must be treated with special care and where measurements should be made. Yarn tension has to overcome frictional forces in flyer spinning and in ring spinning. The friction of the traveller on the ring varies directly as the centrifugal force. Yarn tension in ring spinning and in pot spinning may be influenced by altering the centrifugal force which is governed by the spindle speed, but this is not possible in flyer spinning.

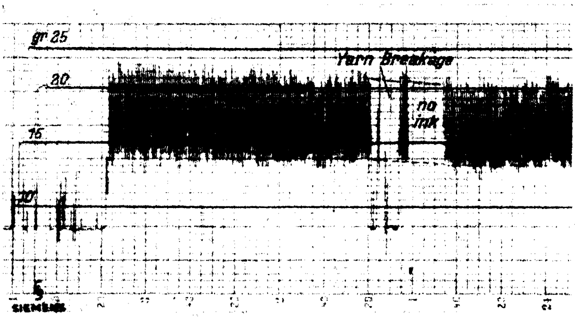


FIG. 7

These brief statements suffice to show that yarn tension generally increases with spindle speed. It depends also on the radius of that part of the bobbin, on which the winding is taking place, since a bobbin of small diameter results, as is known, in increased yarn tension, and vice versa. With the ring spindle the yarn tension decreases by the gradual shortening of the balloon as spinning proceeds.

Yarn tension is tested by the operator in the mill by the feel of the finger, but this method is essentially crude and qualitative only. In the first attempts to measure yarn tension, mechanical appliances were used. A device of this kind is illustrated in Fig. 2. It may be graduated by direct loading with known weights. Mechanical instruments generally strain the yarn too much and

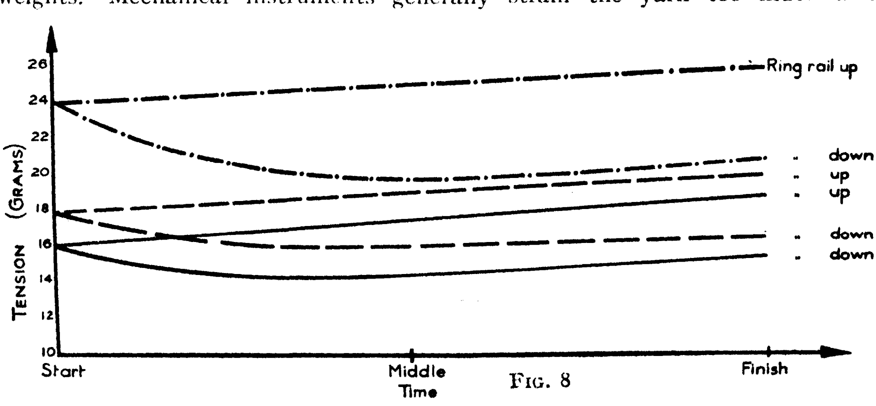
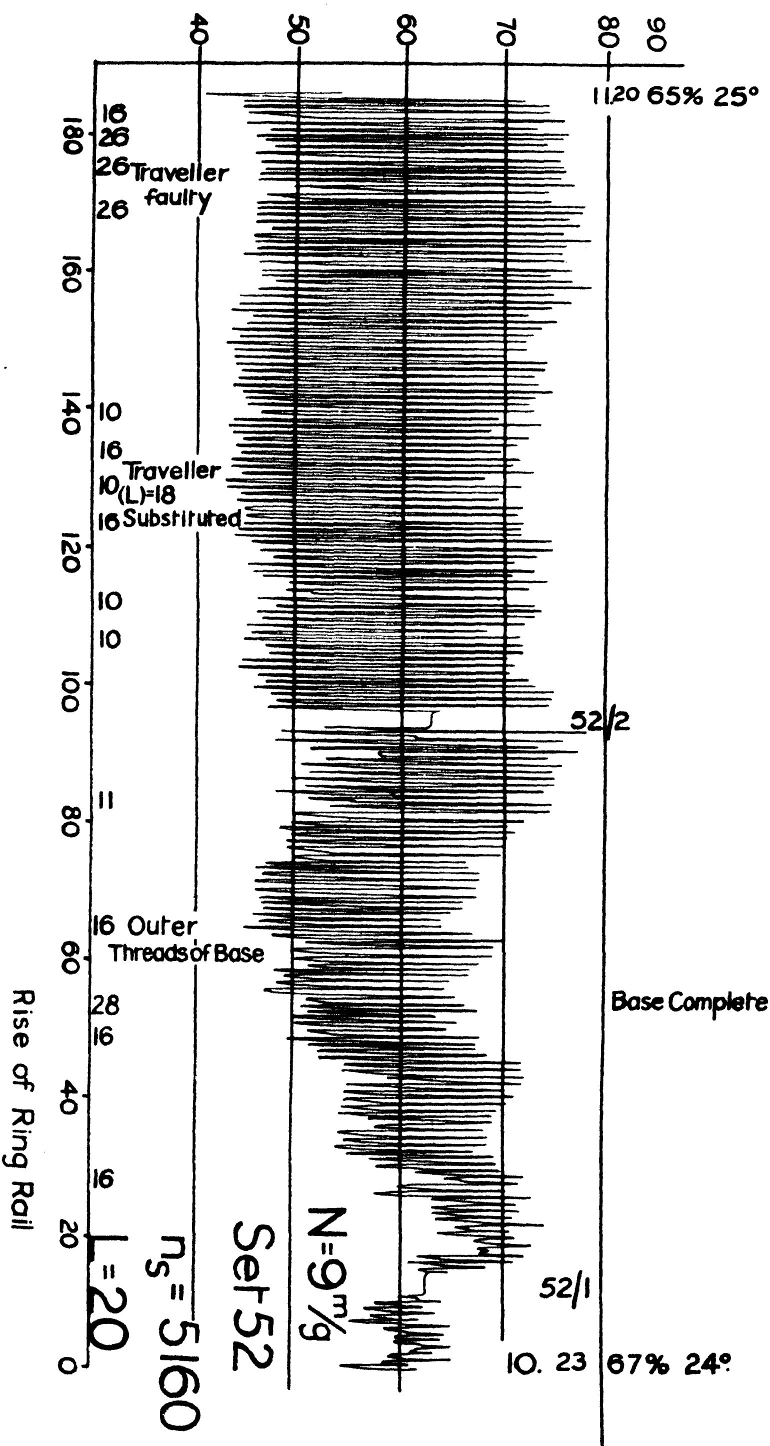


FIG. 8



40
50
60
70
80
90
11.20 65% 25°
16
26
26 Traveller faulty
26
10
16 Traveller
10 (L)=18
16 Substituted
10
10
52/2
11
16 Outer Threads of Base
28
16
Base Complete
16
52/1
10. 23 67% 24°
N = 9 m/g
Set 52
n_s = 5160
L = 20
Rise of Ring Rail
0
20
40
60
80
100
120
140
160
180

FIG. 9

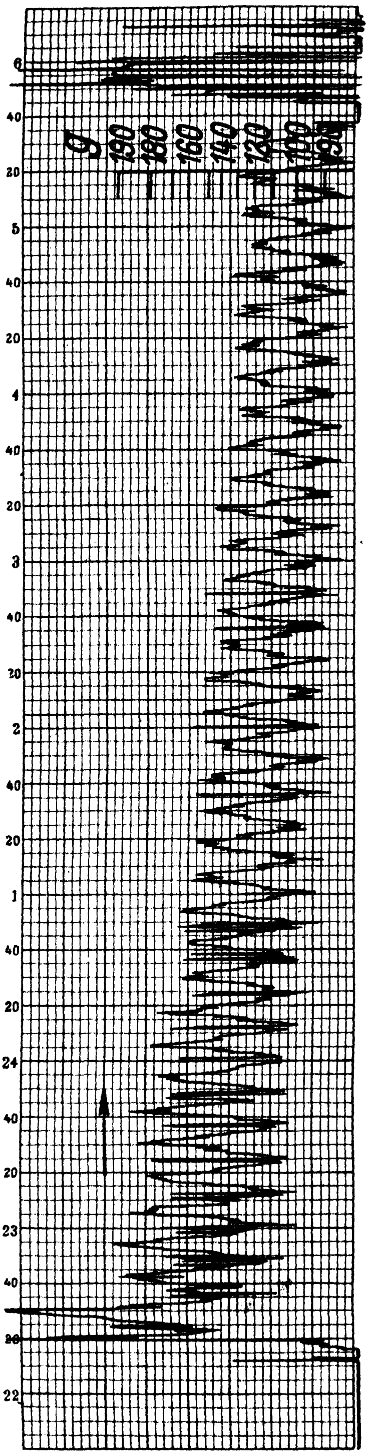


FIG. 10

interfere with the distribution of twist, causing numerous yarn breakages. The oscillations of the weighted lever also impair the exactness of the readings. But the greatest objection is that a registering device can be applied only with difficulty and at high cost. Hence, all tension values must be ascertained separately and be plotted on a diagram. If conclusions of any value are to be drawn, it is necessary to obtain conveniently a series of diagrams and for this purpose a continuously recording device is indispensable.

Messrs. Siemens-Schuckert, Berlin, have constructed to my direction an electrical yarn tension recorder, shown in Fig. 3, consisting of a measuring head arranged on a supporting rod. The tension is tested by a small feeler roller which is lightly pressed against the yarn by a spring. The feeler roller moves through a fraction of a mm. only. Any changes of its position are transmitted by a low current measuring device to a measurement box with pointer instrument and thence by cables to two pieces of recording apparatus. One of them runs slowly and gives the complete yarn tension record from the empty to the filled bobbin. The other apparatus is provided with a faster paper feed and shows the changes of the yarn tension on a larger scale during the separate ring rail chases.

This yarn tension recorder can be conveniently attached to any spindle or spinning frame. The outstanding feature of the measuring appliance is that its application is not limited to the laboratory as it does not require an amplifier or an oscillograph. Small currents suffice to actuate two ink recorders so that measurements may be made during service and tests may be conducted on the spinning frame proper while it is operating.

Records of such tests for yarn tension on a cotton ring spinning frame showing the variations in a complete doffing and in one complete rise and fall of the ring rail are shown on Fig. 4.

The explanation of these diagrams is as follows. A ring spindle is shown in elevation and plan in Fig. 5. The traveller is pulled round the ring by the tension in the yarn. When the yarn is winding on to the bare bobbin, that is, when the ring rail is up, the yarn tension is considerably higher than when the yarn is winding on to the filled bobbin with the ring rail down. During

each ring rail chase (after the completion of the starting period) the yarn tension fluctuates continually between these two limits. The effect of the changes in size of the balloon must also be noticed. At the beginning the ring rail is down, the balloon is long and the yarn tension high. Finally, the balloon is short but the yarn is being wound on the bare bobbin. Thus these two factors partly counteract one another as regards the yarn tension. The two parts of Fig. 6 give this information for a worsted ring spinning frame.

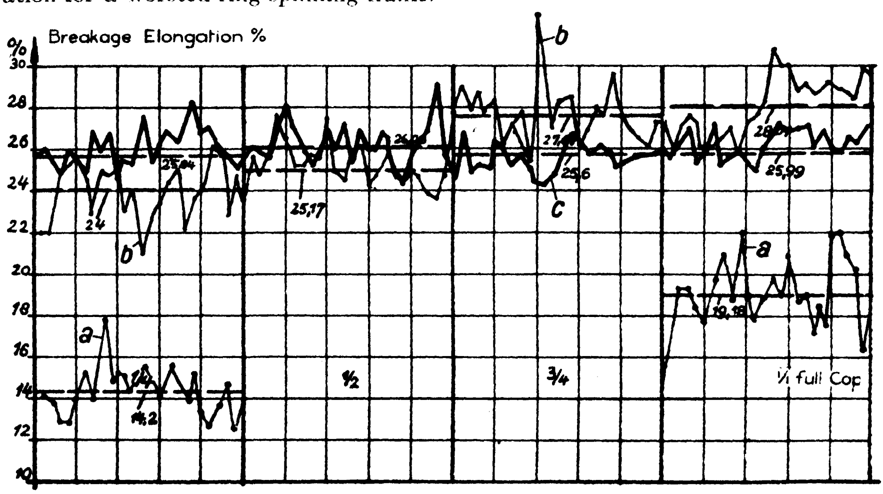


FIG. 11

Fig. 7 in three parts gives further illustrations, the middle portion of one record being omitted, for worsted yarns of 28 and 14 metric counts. Fig. 8 shows for worsted yarn (Nr. 14, metric) how, with the same count, the diagram of the yarn tension discloses an upward trend of yarn tension with an increase of spindle speed, and how the fluctuations grow relatively larger.

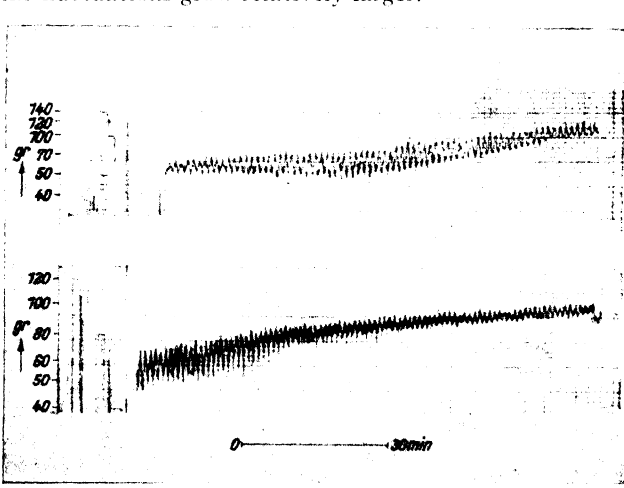


FIG. 12

Measurements of yarn tension on the ring spinning frame for carded woollen yarn, which has now been adopted in England to some extent, have also been made. The frame operates with a revolving tube which produces a so-called false twist in imitation of the twist distributing conditions of the self-acting mules. Provision is made for the pneumatic introduction of the roving in piecing broken threads. The measurements of yarn tension, shown in Fig. 9, exhibit variations between 45 gr. and 75 gr. The fact that yarn tensions are not higher when commencing the spinning is due to the rings of this machine being lubricated after each doffing. This, however, was noticeable in its effect on yarn tension only for about half of the run. This ring spinning process is used not only for conical bobbins but also cylindrical bobbins. The latter shape is used in producing cord thread for automobile tyres.

Fig. 10 gives a continuous record of the yarn tension of a doubling machine with 23/5 × 3 cord. The fluctuations, which are unusually wide, range from 80 to 190 gr. owing to the large ring rail lift.

In this connection the disadvantages resulting from fluctuations in yarn tension during the spinning and doubling of these yarns may be considered. For automobile tyre fabrics it is essential to secure uniform elongation in both warp and weft yarns. Irregularity as regards elongation leads to local failure in service, and this is the first step towards the premature destruction of the whole tyre.

At the beginning, when yarn tensions are high, part of the elongation of the future thread is absorbed in advance in the working up of the material. The finished thread finally retains only about 14 per cent. elongation. With the filled bobbin conditions are reversed and the yarn may have an elongation of 20 per cent. The facts are represented in Fig. 11. Such differences are prohibitive in cord threads and lead in many cases to a rejection of such yarns by cord weavers. There are certain ways of avoiding such defects in spinning and doubling, which will be explained later. The present object is to point out that the yarn tension recorder has disclosed very material fluctuations in yarn tension with all kinds of spindles.

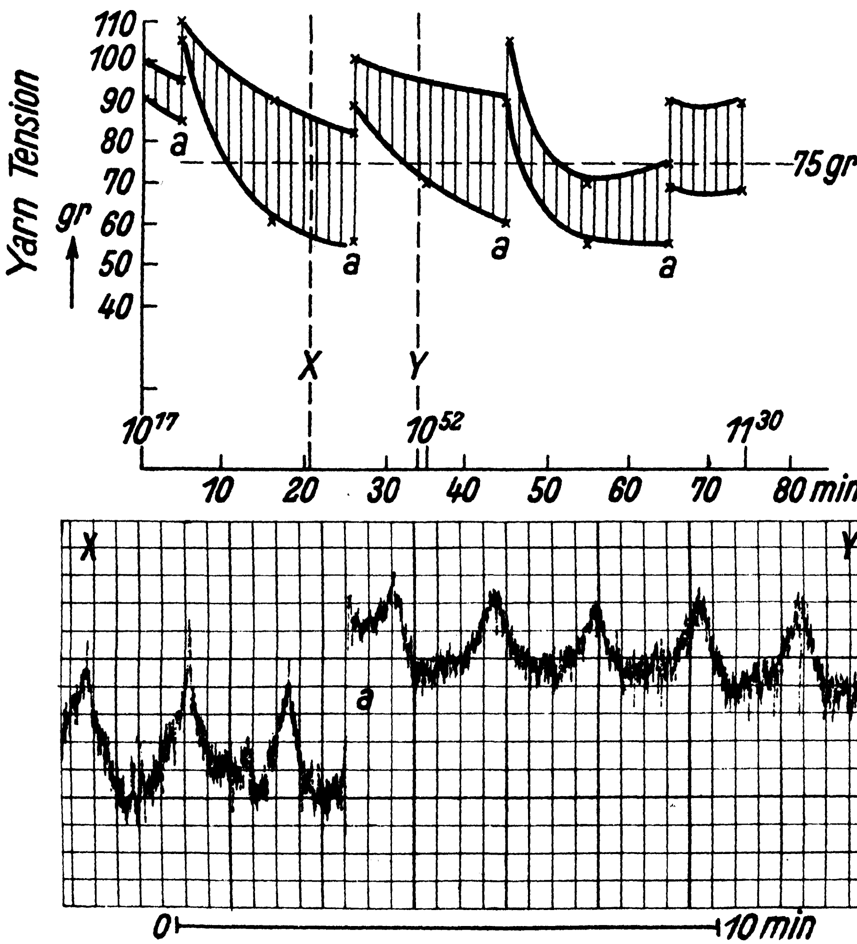


FIG. 13

The application of yarn tension measurements with the object of improving manufacture may now be discussed. It will be necessary to consider the flyer spindle and some measurements of yarn tension on flyer frames spinning flax yarn. Fig. 12 gives for a machine with 3-inch spacing and spindle speed of 2,800 revolutions per minute, spinning flax yarn 20's English, the yarn tensions in grams measured between the delivery rollers and the thread guide during one doffing. The object was to find how yarn tensions vary throughout the entire doffing, if the cord brake is not adjusted at all. The bobbin brake was applied at the start to such an extent that the yarn was somewhat too taut and did not

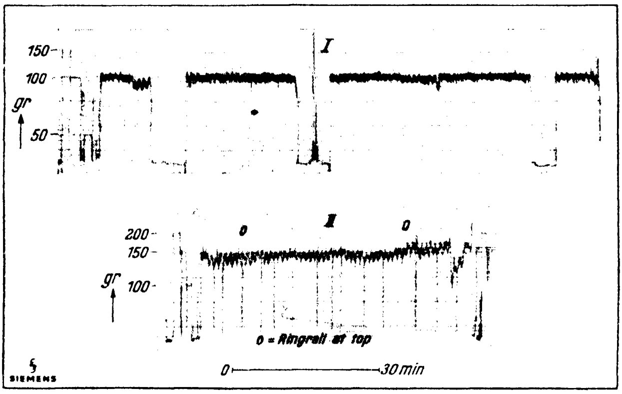


FIG. 14

become slack up to the end. It will be noted that here too the yarn tension decreases more and more as the bobbin becomes filled. It might be argued that spinning is not done this way and that the purpose of the cord brake with the flyer spindle is to increase from time to time the loop angle on the bobbin whorl and so compensate these differences. For a spindle braked normally the record of tensions is shown in Fig. 13. The lower part of the diagram shows how the

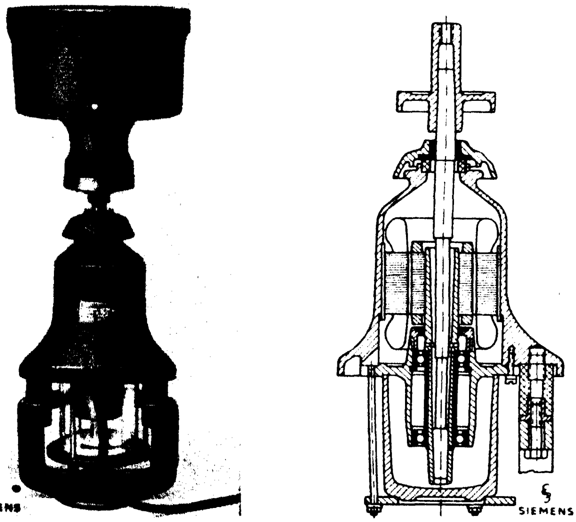


FIG. 15

yarn tension goes up as soon as the brake is applied more tightly. These applications of the brake are marked each time with the letter " a." Notwithstanding regular adjustment of the cord brake, the yarn tensions as a whole are seen to be scarcely less variable than in the preceding case. Thus the cord brake of the flyer spindle is very imperfect and many efforts have been made to improve it.

In Fig. 14 the brake cord on the spindle was guided by hand, according to the indication of the tension measuring instrument. A very clear-cut and uniform yarn tension record was obtained.

The bobbin with the constant yarn tension showed an increase in breaking strength of 22 per cent., in elongation of 15 per cent., and in uniformity of 20 per cent. This was considered to be due to the fact that the yarn tension could be compensated to $\pm$ 5 per cent. (as compared with the former $\pm$47 per cent.) and, in addition, was raised to the higher amount of 105 gr. (as compared with 85 gr.). If this result could be obtained in ordinary production, a given raw material mixture could be spun to increased strength or a higher count, or the same quality of yarn could be obtained with an inferior mixture of spinning material. This is an example showing how measurement of yarn tensions is instrumental in finding out and developing possibilities of improvement.

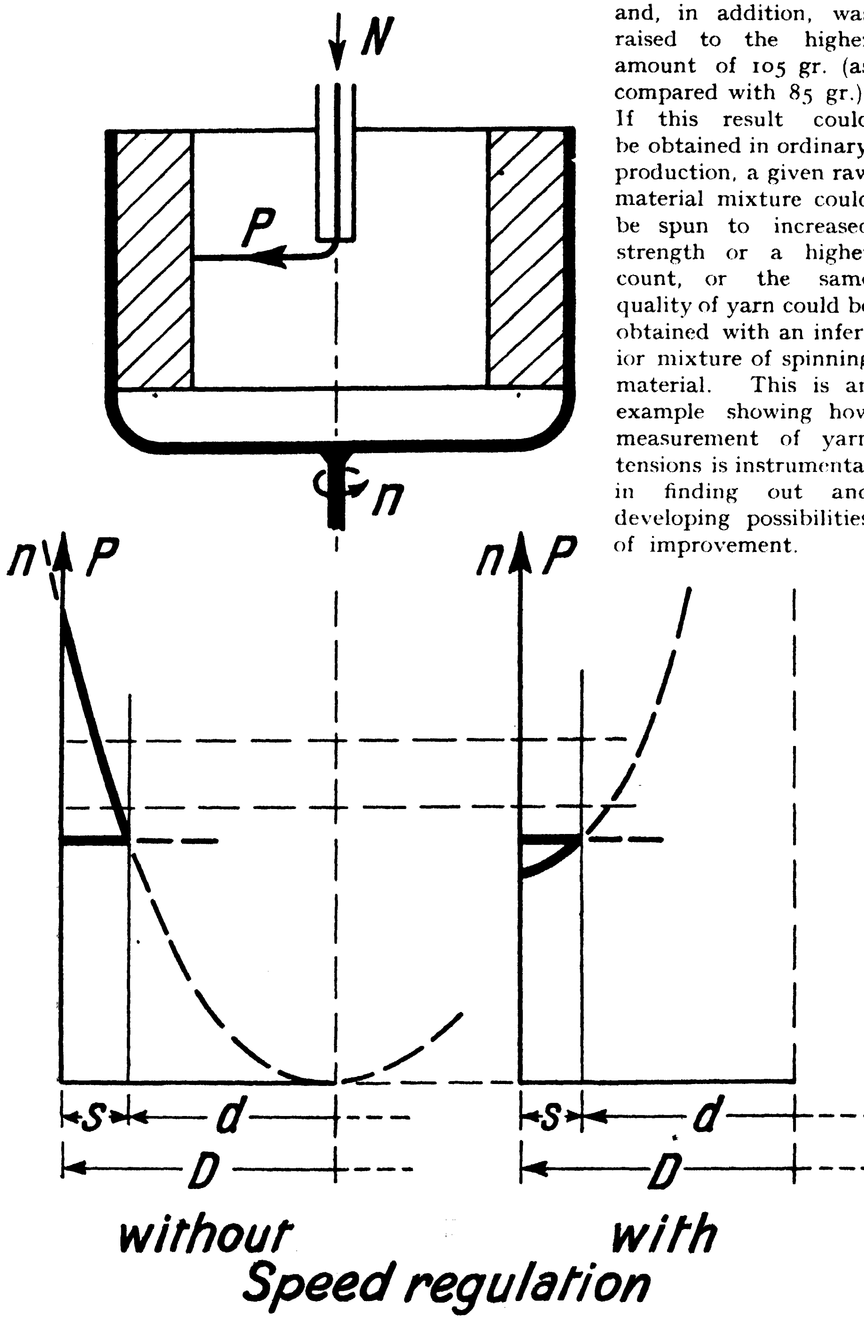


FIG. 16

An electrically driven spinning pot as used in the manufacture of artificial silk is shown in Fig. 15. This construction embodies features which make it possible for this spinning element, equipped with the simple and reliable three-phase squirrel cage motor, to run continuously at 15,000 r.p.m. or more when using

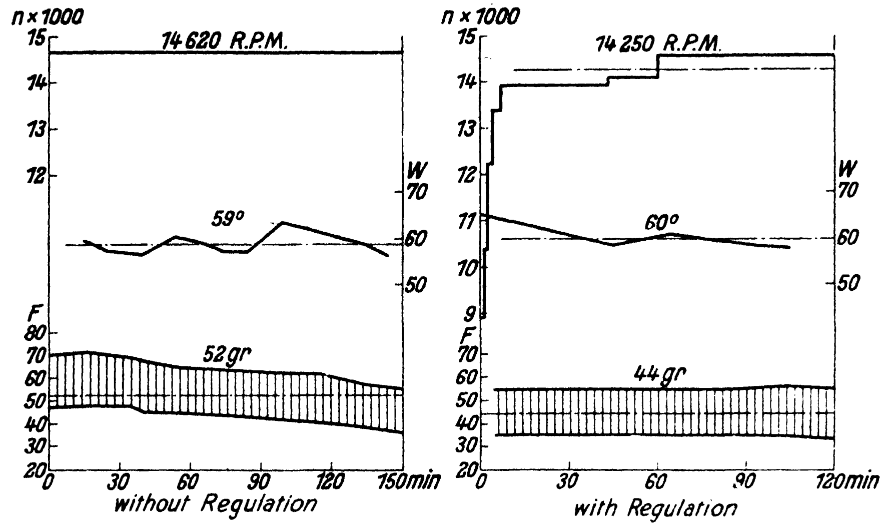


FIG. 17

a frequency changer. Messrs. Siemens-Schuckert at their works in Berlin have experimented in spinning flax yarn at 15,000 r.p.m. and above. The yarn was regular though its strength did not come up to expectations, being one-fifth to one-quarter less than that of flyer yarns. In pot spinning the part of the yarn subjected to centrifugal force is continuously shortened. Consequently the tension of the yarn diminishes in accordance with a parabolic law. If the speed of the pot is increased to compensate for this reduction in the centrifugal force,

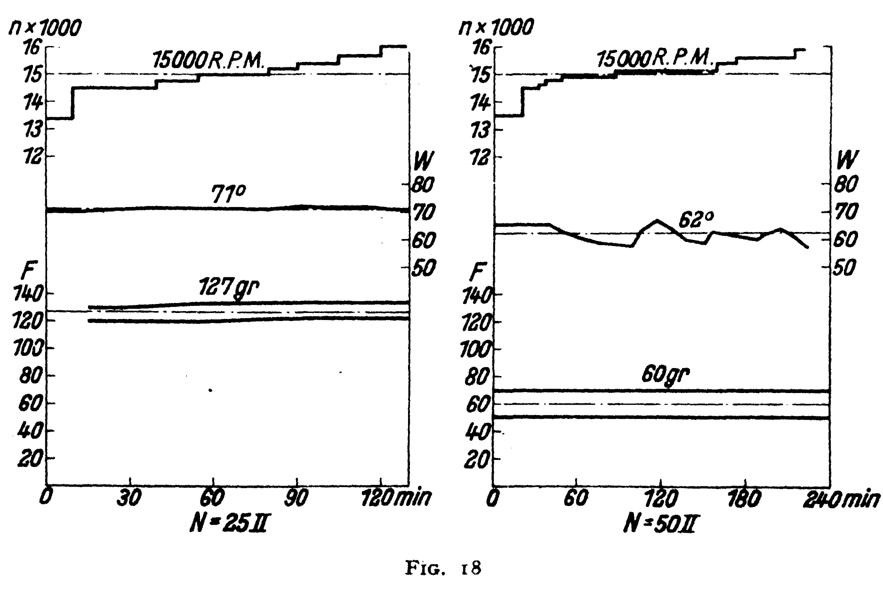


FIG. 18

the tension of the yarn is maintained at the desired value. Tests proved that this method of regulating the speed at the frequency transformer improves the yarn both in strength and elongation by values greatly in excess of those of normal flyer yarns. Figs. 16 and 17 represent the results obtained. Though constant, the tension in the yarn (40/2's English) was too low and consequently the yarn strength was about 27 per cent. below that of normal flyer yarns.

A larger pot was used in the two tests represented in Fig. 18. This permitted, by means of speed regulation, constant yarn tensions corresponding to each yarn, namely, for counts 25/2's flax up to 127 gr. and for counts 50/2's

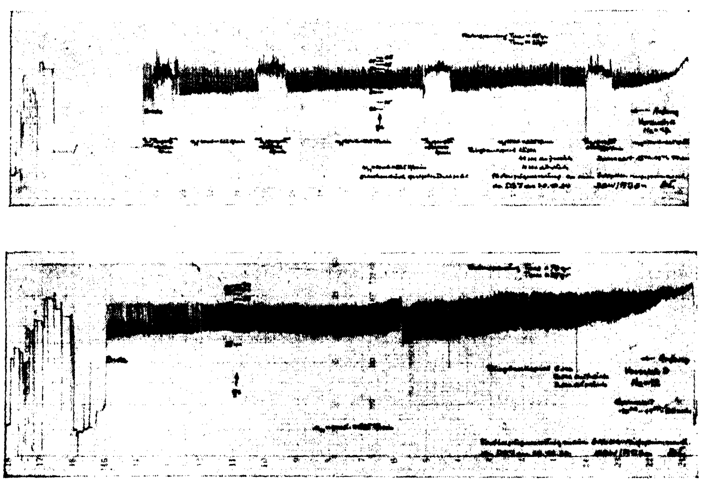


FIG. 19

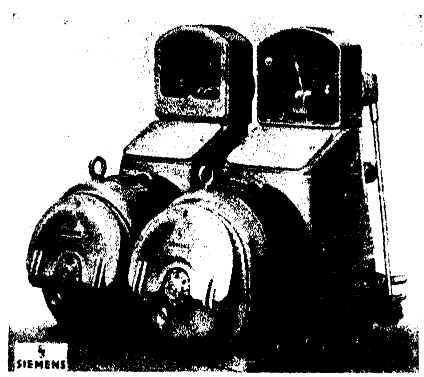


FIG. 20

up to 60 gr. By this method breaking strengths 18 per cent. above the calculated value for the same kind of flyer yarns were obtained, with about three times to four times higher production. The foregoing tests confirmed the view that for increased production of better yarns the tension in spinning must be kept as constant as possible and should be brought to a certain value corresponding to the kind of material and the count of the fibre. Speed regulation, as is well known, can be attained satisfactorily only by means of electrical drives. As noted above, yarn tension records thus serve not only for detecting possibilities of advancement, but for the practical application of such improvements, and for supervising ard ensuring their most favourable working.

In the last few years manufacturers of spinning machines all over the world have made changes in ring spinning frames with the object of maintaining a uniform yarn tension. Equalisation of yarn tension to a slight extent may be attained by the well-known anti-balloon device. The constant balloon length, obtained by fixing the ring rail and imparting a gradual downward movement

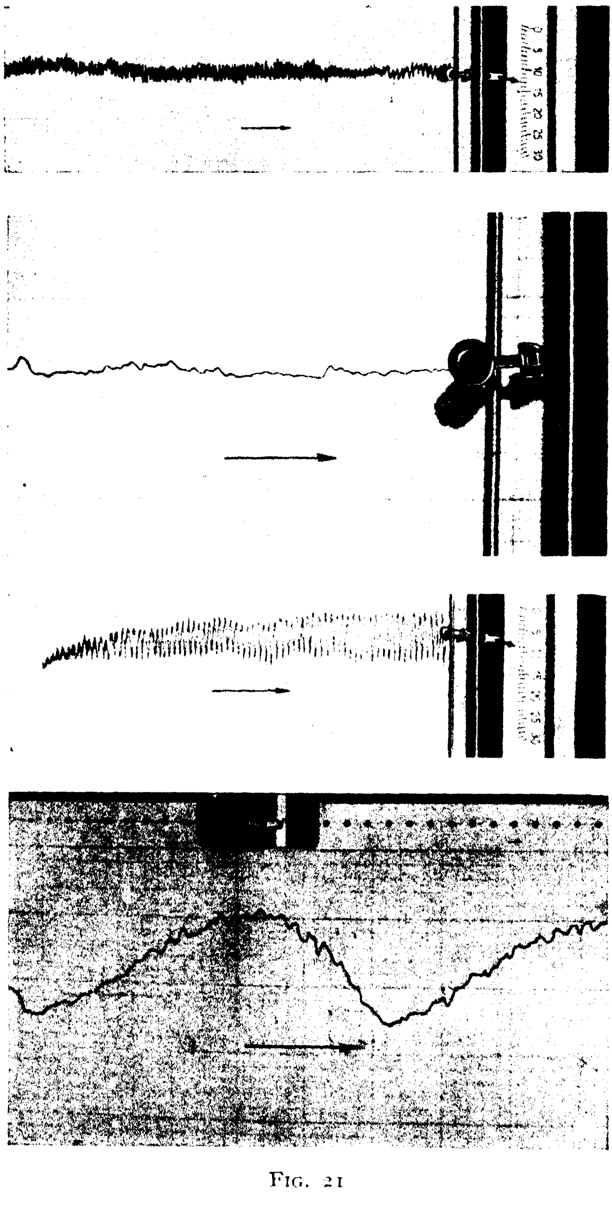


FIG. 21

to the spindle tends in the same direction. These changes do not eliminate the undesired variations in yarn tension, due to the fact that the diameter of the part of the bobbin on to which the yarn is being wound is changing continuously.

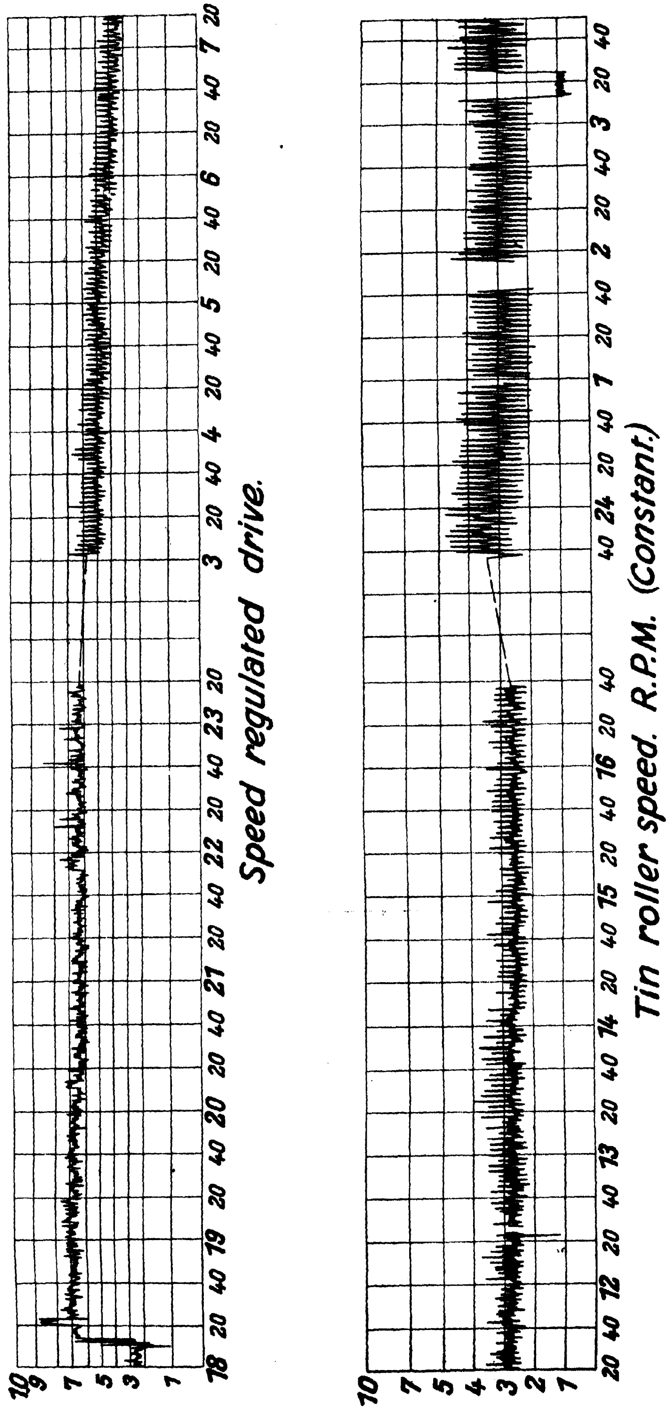


FIG. 22

Yarn tension records (Fig. 19), from an inclined ring spindle, disclose variations of the same magnitude as with ordinary spindles. In the lower part of Fig. 19 the equalisation of the yarn tension was obtained by simply traversing by hand the controlling lever of the driving three-phase motor. If this effect is to be achieved automatically the first requisite is a driving motor effecting steady and finely graded changes of speed exactly according to control, without being affected in any way whatever by external influences, such as variations of line voltage or changes of load. A mechanical regulator is also required to control the motor according to the ring rail traverse and the progressive lift of the ring rail. The " Siemens Spinning Motor with built-on Spinning Regulator," shown in Fig. 20, is designed to this end. The four parts of Fig. 21 show how the use of the Yarn Tension Recorder enables the correct limits of regulation to be determined, giving the variations on a cotton ring spinning frame with and without regulation. In Fig. 22 similar records from a machine spinning 40's Vistra yarn are shown.

Attention was drawn above to the difficulties in selling tyre fabric yarns with variable elongation, and the great economic importance of regulation is proved especially in the case of cord yarn. Other instances are known, where doubling with constant speed of artificial silk yarns for ladies' dress materials has resulted in considerable weaving faults.

FIG. 23.

Fig. 23 is a view of a mill in which variable speed regulating drives are installed. Fig. 24 shows a worsted yarn ring spinning mill. In this instance it was found preferable for economic reasons to install two variable speed drives on each machine. In view of the frequent changing of the worsted yarn packages the two sides of the machine should be independent of one another.

Similar good results in regulation have been obtained on ring frames for wool. Woollen yarns are much more irregular than worsted, cotton or Vistra yarns and more difficult to spin on a ring frame. For this reason, therefore, the regulating drive is especially applicable to this high production machine. English woollen spinning mills have taken the lead as compared with German mills in this respect. In general it may be stated that the application of the variable

speed regulating drive to the ring spinning frame (especially with the assistance of yarn tension measurements) results in improved spinning results, which would otherwise have been impossible. Extra-fine cotton yarns up to 180's English counts are now spun on ring frames in Germany. With general speed

FIG. 24.

regulation it is possible to spin Vistra yarn on ring frames directly on to small cops. Previously, with constant speed, only the usual larger cops could be produced and the yarn had to be rewound in small cop form on a second winding frame.

THE JOURNAL OF THE
TEXTILE INSTITUTE

Vol. XXVIII FEBRUARY 1937 No. 2

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

Election of Council of the Institute

A list of vacancies which arise on the Council of the Institute at the end of the current session has been approved for publication in this issue. Ten of the thirty elected members retire annually but are eligible for re-election unless specially disqualified. In this issue, also, forms will be found for the use of members desiring to nominate candidates for the 1937 vacancies. The list of names given below indicates the year in which members of the Council retire :—

1937	1938	1939
Barnes, H. C. (A. T. I.)	Chamberlain, J. (F. T. I.)	Bromiley, H. (F. T. I.)
Chadwick, F. (F. T. I.)	Greg, H. Gair	Crompton, W. B. (F. T. I.)
Davis, Wm.	Haigh, G. (F. T. I.)	Dilks, H. L.
Howarth, Wm.	Lord, R. (F. T. I.)	Gee, N. C. (A. T. I.)
Lishman, W. W. L.	Porter, F. C. (F. T. I.)	Gowie, A.
Nisbet, H. (F. T. I.)	Read, J. (F. T. I.)	Jaques, H.
Stevenson, A. W. (F. T. I.)	Richardson, H.	Kendall, F. (F. T. I.)
Wildt, E. (F. T. I.)	Scott-Taggart, W. (F. T. I.)	Kershaw, S. (F. T. I.)
Wilkinson, W. (F. T. I.)	Speakman, J. B. (F. T. I.)	Slater, F. P. (F. T. I.)
Wood, F. C. (F. T. I.)	Thompson, G. H. (F. T. I.)	Withers, J. C. (F. T. I.)

The Council of the Institute

At the February meeting of the Council, the Annual Report for 1936, Balance Sheet and Accounts were submitted. The Balance Sheet and Accounts were accepted for submission to the members and these will be published in the March issue of the *Journal*. The Annual Report was referred to a small Sub-Committee for final scrutiny and it was decided to include a paragraph referring particularly to the Balance Sheet and Accounts, this also will be published in March.

So far as practicable, details were arranged for the forthcoming Annual Meeting of the Institute which will be held at Headquarters on Wednesday, April 14th. Mr. John Crompton, whose work for the Institute in general, and its Competitions in particular, is well known to all members, is nominated for election to Presidency. Council expressed its hope that as many members as possible would attend the Annual Meeting on this occasion.

As will be seen from the addition-to-members list also published in this issue, over 20 new members from the laundry industry were elected to membership by Council; in practically every instance these new members were nominated for election by Mr. T. C. Petrie, Chairman of the London Section committee. Council unanimously expressed its appreciation of this effort on the part of a Section Chairman and a special letter of thanks was forwarded to Mr. Petrie. The total number of new members elected—38—constitutes a record for the month of February, and closely approaches the record of membership elections for any month of any year. The next meeting of Council was fixed for Wednesday, 17th March.

The Institute's Examination, 1937

The annual Examination conducted by the Selection Committee in connection with applications for the Associateship Diploma of the Institute, is to be held this year in May, Part I on Wednesday, 19th May, and Part II on Wednesday, 26th May. Part I will be held at headquarters and commences at 9-45 a.m. Part II will be held simultaneously at headquarters, Manchester, in Bradford, in Nottingham, in London, and in India, probably at Bombay and elsewhere. At the February meeting of Council, invigilators for the various centres at which the Examination will be held were appointed.

Annual Competitions for the Institute and of the Lancashire County Council

The establishment of the Institute's Competitions dates back to a donation of £2,000 from Mr. John Crompton, O.B.E., M.Sc., F.T.I., of Ansdell and Manchester, the annual revenue from which was to be applied to the provision of prizes with a view to the encouragement of the Design and Structure of woven Fabrics. The first Competition was held in 1919-1920 and entries were for one album of woven samples only. With varying fortune, but with ever-growing appeal the Competitions have gone on from year to year. Additional Competitions have been instituted and now cover single woven fabrics (novel in character) as well as albums of woven specimens, yarns (single and doubled) knitted fabrics, and designs on paper for printed fabrics. In 1936 the Institute received yet another bequest, £1,000 from the late Mr. R. J. H. Beanland, of Clayton West, Huddersfield, the income from which is to be devoted to the provision of prizes for the encouragement of the Design and Structure of Fabrics, and in particular fabrics in the manufacture of which worsted yarns have been used. Two additional Competitions have therefore been added to those already available and the recently issued Competitions Prospectus contains full particulars of all the Competitions now conducted by the " Textiles and Designs Committee."

The Lancashire Education Committee with the object of encouraging practical design and fabric structure again offer prizes in a Competition for collections of not more than four fabrics submitted under certain prescribed conditions, details of which are now available. Full particulars can be obtained from the County Education Offices, Preston.

Honours List: February, 1937

The first list of Honours conferred by His Majesty King George VI was issued on the 1st February. Of particular interest to the Textile Institute were the following awards:—

BARONET. SIR WILLIAM CLARE LEES.
Managing Director of the Bleachers' Association Ltd. For services to the British cotton and artificial silk industries. Sir William was President of this Institute from 1933-34.

KNIGHT. COLONEL GILBERT TANNER.
For political and public services in Yorkshire and Lancashire. Colonel Tanner is a member of the Institute.

At its February meeting the Council affirmed its hearty appreciation of and congratulations upon the awards recorded above.

Representation of the Institute on other Organisations

The Institute is now represented upon several organisations and the following list may be of some interest and use.

Joint Committee of the Board of Education and of the Textile Institute for the Conduct of the National Certificates in Textiles Scheme.

REPRESENTATIVES OF THE BOARD: H.M. Inspectors J. E. Dalton, H. Salt, H. J. Shelley, and P. F. Burns.

REPRESENTATIVES OF THE TEXTILE INSTITUTE: Messrs. F. W. Barwick, J. H. Lester, T. H. Robinson, and S. E. Ward.

Empire Cotton Growing Corporation: Administrative Council.
Mr. Frank Wright represents this Institute.

Yorkshire Council for Further Education: County Advisory Committee for Textile Industries.
Mr. E. T. Holdsworth represents this Institute.

British Management Council.
Mr. Frank Nasmith represents this Institute.

Institution of Mechanical Engineers: General Committee to arrange Discussion (October, 1937) on Lubrication and Lubricants.
Mr. W. Scott-Taggart represents this Institute.

Union of Lancashire and Cheshire Institutes: Advisory Committees on Cotton Spinning and Cotton Weaving.
The General Secretary represents this Institute.

Federation of Textile Societies and Kindred Organisations

The Tenth Annual Meeting of the Federation is this year to be held in Huddersfield by invitation of the Huddersfield Textile Society. The date fixed for the event is Saturday, 1st May, and already an attractive programme has been outlined. At a recent meeting of the Committee of Management of the Federation the above arrangements were approved and it was also recorded that the Haslingden Textile Society had accepted the Committee's invitation to nominate a President for the ensuing year. The election of President takes place at the Annual Meeting, together with the election of members of the Committee of Management, four of whom are drawn from Lancashire Societies, three from Yorkshire Societies, and one from the Leicester Textile Society. The Committee is completed by two representatives of the Textile Institute, together with an Hon. Auditor and Hon. Secretary. The Federation two years ago offered a prize of £5 for the best lecture delivered to a Federated Society by one of its members or by a member of an affiliated body. Each Society was invited to select one paper so contributed and all entries thus submitted were adjudicated upon by the Committee of Management. This prize is again offered to cover papers delivered during the Sessions 1935-1936 and 1936-1937; all entries should be sent to the Hon. Secretary, c/o The Textile Institute, on or before the 31st March next. At the close of the Committee meeting referred to above members were entertained to tea by the present President, Professor F. Bradbury, of Belfast.

Second Conference on Industrial Physics

The second Conference on Industrial Physics will be held under the auspices of the Institute of Physics in Birmingham, from 18th to 20th March next. The subject of the Conference is "Optical Devices in Research and Industry." An Exhibition of instruments, apparatus and books cognate to the subject of the Conference is being arranged, and will be held in the Physics Laboratories of the University of Birmingham. A section will be devoted to popular applications of optical devices, including photocells. The Presidential Address on "Spectroscopy in Industry" will be delivered by Prof. A. Fowler, C.B.E., D.Sc., A.R.C.S., F.Inst.P., F.R.S., and in addition lectures and discussions on the following subjects are being arranged: "Colorimetry, Spectrophotometry, and the inspection of manufactured products for 'appearance'," "Polarimeters, Saccharimeters and Refractometers in Sugar, Jam-boiling, and other Industries," "The Application of Electron Diffraction to Industrial Problems," "The Industrial uses of Photocells," "Optical Gauges for Metrology and Engineering." It is intended that the lectures and discussions shall be informal in character;

they will deal particularly with applications of the subject to industrial problems. Visits to local works and research laboratories will be included in the programme and a Conference dinner will be held. There will be no Conference fee and membership is open to all interested. Further particulars may be obtained from the Secretary, The Institute of Physics, 1, Lowther Gardens, Exhibition Road, London, S.W.7.

TEXTILE INSTITUTE DIPLOMAS

Elections to Fellowship and Associateship have been completed as follows, since the appearance of the previous list (January issue of this *Journal*) :—

FELLOWSHIP

KENDALL, Frank (Shipley)
SHACKLETON, George (Bradford)
WILDT, Edwin Mary Hubert (Leicester)

ASSOCIATESHIP

CLARKE, George (Long Eaton, Notts.)
HODGSON, Wilfrid (Baildon)
WILLIAMSON, Edward Geoffrey (Bradford)

Employment Register

The following announcements are taken from entries in our Register of members whose services are on offer. Employers may obtain full particulars on application :—

No. 152—A.T.I. requires position as Assistant Manager, Manager or Works Chemist to Woollen Manufacturers. B.Sc. in Applied Chemistry. Prepared to go abroad. Leeds University Diploma in Dyeing. Age, 34 years.

No. 153—Desires position as Textile Technologist or Technical Adviser to Private Firm or Public Body. 15 years' experience in Hosiery Trade. 5 years' experience at Public Testing House. Knowledge of Costing, Factory Management, Past Examiner. A.T.I. Fellow of Royal Microscopical Society. Age, 34 years.

No. 154—Requires position in Pure Silk dyeing works, or Manufacture Departmental Manager. Nottingham University College Diploma in Textiles. City & Guilds Final Grade Certificate in Hosiery. Age, 24 years.

No. 155—Requires position as Carder, Assistant Manager or Research or Experimental Dept. of Rayon Industry. Full Technical Certificate. Prepared to go abroad. 14 years' experience as Carder and 2 years as Manager. Age, 39 years.

No. 156—A.T.I. requires position as Designer Manager, Designer Salesman or Technical Manager in large concern. City & Guilds 1st Class Final in Woollen Spinning. Leeds University Diploma in Textiles. Nine years' teaching experience in Textile Design and Colour Study, also Textile Finishing and Woollen Spinning. Age, 38 years.

Institute Membership

At the February meeting of Council, the following were elected to Membership of the Institute :—

Ordinary.

H. Adams, Textile Paper Tube Co. Ltd., Percy Road, Aylestone Park, Leicester (Representative).

H. Arnold, 430, Crompton Way, Tonge Moor, Bolton (Full-time Lecturer and Demonstrator in Cotton Manufacture, Bolton Municipal Technical College).

A. C. Bull, Birds Laundries, 1, Claremont Road, Newcastle-on-Tyne (Manager).

Wm. A. Chamberlain, 2, Warwick Gardens, London Road, Thornton Heath, Surrey (Laundry Manager).

F. B. Channon, Watson's Laundry, Abbey Road, Belvedere, Kent (Manager).

J. F. Charlwood, Kingston Regional Laundry, Wolverton Avenue, Kingston-on-Thames (Laundry Manager, Surrey County Council).
V. P. Davies, The Carmarthen Steam Laundry, Priory Street, Carmarthen (Manager).
H. Dorcey, 59, Leadale Road, Stamford Hill, London, N.16 (Laundry Manager).
A. Firth, 28, Jedburgh Street, London, S.W.11 (Inspector of Textiles, India Store Depot, Lambeth).
G. W. Harrison, County Hall, Kingston-on-Thames, Surrey (Chief Laundries Officer, Surrey County Council).
N. V. Haywood, Crown Laundry Co. Ltd., Rigault Road, Fulham, London, S.W.6 (Laundry Director).
R. H. Mitchell, Ivy Dene, Ashurst Wood, E. Grinstead, Sussex (Laundry Manager).
M. P. Monzoni, B.Sc. (Eng.), Rua Argentina 674, Jardin America, S. Paulo, Brazil (Assistant Manager of Cotton Mills and Print Works).
Miss E. G. Murray, Royal Laundry, Ongar Road, Brentwood, Essex (Laundry Manageress).
H. H. Nicoll, 6, Brantwood Avenue, Dundee, Scotland (Clerk, Francis Stevenson and Sons Ltd., Dundee).
O. Pomfret, 213, Bolton Road West, Ramsbottom, Manchester (Manager and Director of Towel Mill).
R. H. Rogers, 88, Bassetts Way, Farnborough, Kent (Cedars Laundry, Farnborough).
J. E. Shaw, 118, Watling Road, Fulwood, Preston (Manager, Dyeing Dept., Horrockses Crewdson & Co. Ltd., Preston).
R. Siegl, 527, Bahnhofstr., Oberleutensdorf, Czechoslovakia (Inside Manager of E. G. Pick, Cotton Mill).
F. Stein, c/o Messrs. E. G. Pick, Oberleutensdorf, Czechoslovakia.
J. T. Strachan, 9, Links Road, West Acton, London, W.3 (Superintendent, Savoy Hotel Laundry, 376, Clapham Road, London, S.W.9.).

Junior.

H. Bagot, 83, Green Lane, Garden Suburbs, Oldham (Student, Manchester College of Technology).
E. G. Bell, The Firs Hotel, Poynders Road, London, S.W.1. (Laundry Student).
G. R. Bide, West End, Havant, Hants (Laundry Manager).
J. Brear, B.Sc.Tech., 173, High Street, Chorlton-on-Medlock, Manchester, 13 (Research Student).
D. W. A. Clarke, " Westland," Great Woodcote Park, Purley, Surrey (Laundry Student).
G. Finlayson, 17, Clare Hill, Huddersfield (Assistant in Designing Dept., Learoyd Bros., Huddersfield).
G. N. Freck, 74, High Street, Wimbledon, London, S.W.19 (Laundry Student).
J. D. R. MacGillivray, 5, Atney Road, Putney, London, S.W.15 (Washouse Man, Crown Laundry, Fulham.)
D. Malcomson, Lune Laundry Ltd., Lawrence Road, Liverpool, 15 (Installing Costing System, Investigating complaints, etc).
K. E. Markham, Edgcombe, Tangier Road, Guildford, Surrey (Launderer).
J. Martin, 164, Downton Avenne, Streatham Hill, London, S.W.2 (Assistant Laundry Manager).
R. A. Selwood, 7, Elsdale Street, Well Street, Hackney, London, E.9 (Assistant Laundry Manager).
A. Shaha, College of Technology, Sackville Street, Manchester (Student of Textiles).
S. C. Smith, 62, Bierley Lane, Bradford (Assistant Designer).
J. G. Whitaker, 1, Lynette Avenue, Clapham Common, London, S.W.4 (Manager, St. George's Hospital Laundry, Wimbledon).
H. Wignall, 4, Bardolph Street, Leicester (Hosiery, Factory Executive).
W. F. Woodward, Slade Road, Ilfracombe, N. Devon.

Yorkshire Section.

At a meeting of the Yorkshire Section of the Textile Institute, at Bradford, on the 10th December, 1936, under the Chairmanship of Mr. G. Haigh, F.T.I., the following lecture on "The Recovery of Wool Grease in the Bradford Trade" was delivered by Mr. F. Brock.

The recovery of Wool Grease and the treatment of the wool scouring effluents has been one of the major problems in the wool combing industry since 1897. Local legislation was introduced forbidding the discharge into the sewers by wool-combers and others, of trade wastes that might interfere with the corporation's treatment of domestic sewage. Numerous problems, which are inseparable from this interesting work, still await solution. They are, however, of relatively small magnitude in comparison with the difficulties which the local sewage authorities had to overcome in the early days of the combing industry.

To-day, wool scouring effluents are either treated according to corporation requirements, or they are turned directly into the sewers under agreement with the sewage authorities on payment of 6d. per thousand gallons. Prior to 1897, it was permissible to run all effluents direct into the sewer. About the middle of the last century, Bradford was rapidly developing. The expansion of Bradford was more rapid than that of any other town in England and was both unforeseen and unprovided for by the local bodies. Prior to the industrial revolution, sanitation and effluent problems were comparatively unknown. It was an easy task to run the sewage into the Bradford Beck, which at that time was an open stream running through the centre of the town. Householders living near the stream had no difficulties with their domestic sewage but those living at a distance from the water-courses had their own primitive methods of disposal, which were often a nuisance to their neighbours. As the industry and the population of Bradford increased, so did the volume of sewage which was finding its way into the Bradford Beck and the River Aire. The sanitary conditions in Bradford were rapidly becoming deplorable and the authorities were compelled to realise that something had to be done. A government officer who visited Bradford in 1843, in connection with the public health acts, declared in one of his reports that bad as he had found most industrial centres, Bradford was the most filthy town that he had ever visited, public sewers being unknown in the place. Ancient private drains served the principal streets, whilst the sewage from the other streets was conducted away in open channels. The canal, which at that time was one of the town's commercial assets, added in no small measure to the insanitary conditions which existed. A branch of the canal had been brought up the valley and had its terminal basin almost on the site of what is now Forster Square. Here, sluice gates intercepted the water from the Bradford Beck, the consequence being that the pool became the recipient of vast quantities of sewage. The water in the basin often became so charged with decaying matter that in hot weather, the atmosphere was heavy with sulphuretted hydrogen. The stench was always objectionable and fevers became accepted as a matter of course. The Rivers Pollution Commission which dealt with these problems in the early sixties, described the canal basin as so corrupt that large volumes of inflammable gases were given off and it was comparatively easy to set the Bradford canal on fire. This was an amusing pastime of the local boys.

A charter of municipal incorporation was secured in 1847, and soon afterwards an outbreak of cholera impressed on the Council the necessity of better sanitation. In 1853 the line was laid for a main trunk sewer, but no progress was made until nine years later. It was 1862 before the first mile of sewer was laid and by 1870 thirty miles had been completed. From that date sewering has never ceased and there are now about 120 miles of sewer in the old borough of Bradford. The Beck was covered in and in 1866 that festering pool of corruption, the canal basin, was dealt with. These measures took it for granted that the river was

the natural place for sewage and the better the drainage the worse became the pollution of the Beck and the River Aire.

Other industrial communities were rapidly appearing on the banks of the Aire and were also using the river as the natural outlet for their sewage. The rapid development of the wool-combing industry in Bradford added considerable difficulties to a problem to which at that time there seemed no solution. A fleece of wool may lose in some cases up to 60 per cent. of its weight during the scouring process, the 60 per cent. consisting of the natural fat, foecal matter and the dirt which accumulates on the fleece during growth. It is easily seen, therefore, that the effluent from wool-scouring can be extremely offensive and objectionable if untreated.

As the industry increased in Bradford, numerous protests were made by the residents who lived near the river against the ever increasing nuisance. Mr. Stansfield of Esholt Hall, took his complaint to the Chancery Court, asking that the corporation should be restrained from discharging sewage or offensive filth of any nature into the Bradford Beck in such a manner that the same would pass into the River Aire and cause him annoyance, and to be restrained from polluting the river in any way prior to its course past Esholt Hall. The corporation found themselves in great difficulties as up to this time all methods of precipitation and deodorisation of sewage had proved lamentable failures completely unworkable on a large scale. The Royal Commissioners' did not know how to deal with such cases and it was argued that if the governments most capable servants were in difficulties over the problem, local boards could hardly be expected to find a solution. One suggestion was to construct a very large sewer which would take the sewage from the entire industrial districts of Yorkshire in the valleys of the Wharfe, Aire and Calder, away down to the sea. The government refused to listen to this suggestion and refused to give any financial assistance. Although the court realised the difficulty with regard to Bradford they attempted to forbid any further intensification of the nuisance. They prohibited, under penalty of £10,000, the opening of any additional main or sewer or any house drain into the outfall sewer. This put a limit to the commercial development of the town and satisfied nobody. It did not make the river any more tolerable to the people who lived on its banks.

A year later the injunction was dissolved and the corporation was ordered to take practical measures for defœcating the sewage, before passing it into the rivers. Bradford then started a series of experiments at Frizinghall, the lowest point in the borough. Certain works were constructed and a private company offered to treat the sewage free of cost provided that the corporation erected a building for them and charged no rent. This company failed in about two years, losing £3,000 in their experiment. They had calculated that their profits would be colossal if they could filter the effluent through peat charcoal and sell the residue to the farmers as manure. The corporation carried out further experiments in purification. They eventually succeeded in turning out an effluent which was almost colourless and practically odourless and this system was quite satisfactory for a few years.

Grease was first extracted in Bradford in 1861, but the extracting was done by private grease extractors and not by the wool-combers. The extractors made arrangements with the combers to have the washing liquors cracked with acid on their premises and the resulting precipitates, known as magma, delivered to their extracting plants. The first plant to work this process was dismantled about 1876, as it did not pay, owing to the low prices obtained for grease. As the combing plants developed and the quantity of wool dealt with increased, the price obtained for the grease declined. This resulted in the comber once again running all his effluent into the sewer in an untreated condition. When this happened the sewage works at Frizinghall found it utterly impossible to deal with the increased volume of effluent. In 1889, the amount of grease which

found its way into the Bradford Beck was estimated between thirty and fifty tons per day according to the state of the trade.

After numerous experiments a method was adopted in which the solids were precipitated with lime and the effluent was further purified by filtration through coke-breeze. This method was kept in operation for a few years, but as only a portion of the sewage could be dealt with, the river once again became the outlet for a large volume of untreated effluent. Eventually the precipitation by lime was replaced by another method in which ferric sulphate was used. This was satisfactory in every way, but it proved far too costly. Very good results were obtained with ferric sulphate for it brought about a practically complete separation and left the water quite transparent.

About 1897, as noted above, local legislation was introduced forbidding wool combers to deliver into the sewers any effluent which might interfere with the normal treatment of domestic sewage. Thirty-two firms were fortunate enough to escape from this prohibition, as they argued that they had no space for the erection of grease extracting plants. There are now five firms only who are still turning their effluents into the waterways in an untreated condition, two or three who are allowed to turn untreated effluents into the sewers, as they still hold prescriptive rights and a few who turn untreated effluents into the sewers with the corporation's permission on payment of 6d. per thousand gallons.

It was 1901 before the Bradford Corporation started to use sulphuric acid as the chemical agent for precipitating the solids from the effluent. Most of the local combers had also adopted acid treatment. This has held its own up to the present time and although it cannot be said to be all that is desirable, it certainly answers its purpose and allows the comber to turn out an effluent which complies with the corporation's requirements.

Wool combers' effluents are the liquors from the wash-bowls containing detergents such as soap and alkali, impurities from the wool consisting chiefly of the wool-grease held in suspension by the detergents, large particles of sand, excrement in small quantities, fine particles of clay in an almost colloidal state, the soluble salts of perspiration known as suint, and vegetable fibres and burrs. The recovery of wool grease from the scouring liquors is accomplished in various ways.

One of the oldest methods of recovery is known as the battage process which may be regarded as the forerunner of some of the modern aeration processes. The oldest and the commonest method employed in the Bradford trade is the Magma process, in which the liquors are subjected to cracking, usually by means of sulphuric acid. In this method, the grease and the fatty acids from the soaps are separated from the liquors and extracted by hot pressing.

Another method is the centrifugal process. Several types of centrifuges and separators have been tried during the last 50 years, but only two are reasonably successful. These are due to Duhamel and Adams respectively.

The solvent process of extraction is usually worked in conjunction with the scouring of wools by solvents, such as benzene or ethyl chloride.

Acid Cracking Process

The acid cracking process is the commonest process employed in England and is likely to remain so as long as our corporations and rivers boards insist on all effluents being in an acid condition. There are degrees of efficiency in this process, for some combers are quite satisfied if they produce one ton of grease for every 30 cwts. of acid used, whilst others consider that a yield of 1 ton of grease per ton of acid should be obtained.

Settling tanks and mechanical agitation undoubtedly play a large part in the results achieved. Some firms pass their liquors through a primary tank in which the heavier mineral matter settles out. The liquors overflow into large tanks and sulphuric acid is added. Mixing is done by means of hand

paddles and a perforated steam pipe. Usually, the same amount of acid is added to each tank irrespective of the alkalinity of the liquors. The men in charge of the cracking rely entirely on the taste of the liquor to determine whether sufficient acid has been added. It is obvious that by this method of treatment some tanks may contain a considerable excess of acid, whilst others may remain slightly alkaline.

The magma is usually run on to a filter where further liquor is drained off. It is then shovelled into canvas wrappers, known as puddings, and the puddings are pressed in screw or hydraulic presses. The labour costs for a process of this type are very heavy for the filters are constantly being renewed and all the magma is moved by hand labour. Sometimes three handlings are required before the magma reaches the presses. When the grease is extracted, each pudding is again handled separately in the operation of emptying the press and removing the sudcake from the cloth. This mode of operation would be utterly impossible in a large mill where the volume of untreated effluent sometimes amounts to over a third of a million gallons per day.

A better method where space permits is to replace the primary tank by a series of vats or tanks with mechanical agitators. When the vat is almost full, the acid can be run into the effluent through a measure marked in gallons. The agitating sticks are kept in motion whilst the acid is running into the effluent and by this means a good separation can be obtained with a definite excess of sulphuric acid, regardless of the strength of the effluents. The treated effluent is then pumped from the cracking vats into large settling tanks (with a capacity of 160,000 gallons). After settling from 8 to 12 hours the magma is completely deposited on the bottom of the tank and the supernatant liquor containing seldom more than 20 to 55 grains of grease per gallon can be run away to the drains with perfect safety. The magma is blown by steam or allowed to run by gravity to a sludge pump which forces it, first into a steam kettle in which the temperature of the magma is rapidly increased and from there into a large upright boiler. Steam is finally applied in the upright boiler and the boiling magma is forced through filter presses. These presses will run from 10 to 14 hours, according to the amount of sand present in the magma, and the grease and water flowing away from them are separated by an overflow, all the water being returned to the tanks containing the untreated effluent. The grease is clarified in order to get rid of any traces of magma, washed and barrelled. A method of this type can be worked much more economically and efficiently than the previous method, as labour costs are reduced to a minimum. The sud cake is hard and contains about 20 per cent. of water and about 14 per cent. of grease. If the effluents are not properly treated in the cracking vats, the uncracked soaps in the magma are a source of trouble in the press house. The filter cloths become clogged with sludge and the presses cease to function after running about half the usual period. The cake is a soft watery mass containing a higher grease content and is very difficult to handle. It is absolutely essential to form this solid cake, in pressing, in order to keep the filter cloths clean for subsequent filtration.

Adams Centrifugal Process

As far back as 1884 one well-known firm of Bradford wool-combers was experimenting with cream separators. The product which they obtained was of an extremely good colour but the scheme was impracticable on account of the tremendous volume of effluent which had to be treated. It was about this time, 1884, that lanoline was first made in Germany by a centrifugal method. In 1900 the Smith Leach process of recovering grease was evolved. In this process the liquor was first passed through an evaporator which reduced it to one-tenth of its volume and the concentrated mass was then passed through a large bulk type separator to remove the solid matter and extract the grease emulsion. This emulsion was purified in another separator whilst the mother liquor was con-

veyed to a calcinator to recover the potash. The failure of this process was due to the separators being unable to remove a sufficient quantity of grease, the grease remaining in the mother liquor causing the products of calcination to be a useless, sticky mass, unfit for conversion.

Further attempts to recover grease centrifugally were made in 1920, as at that time the price of grease was extremely high. The effluent was allowed to stand from 24 to 48 hours when it was found that it could be passed through an ordinary type of separator and the grease recovered. This method became impracticable as soon as grease prices dropped, as it was proved to be uneconomical to allow the liquors such long periods of settlement. The large number of storage tanks required made the expenses of such a plant prohibitive and when the liquors were passed through the separator after allowing to stand for only a few hours the finely divided mud which was held in suspense soon choked the machine.

The Adams machine appeared about seven years ago. If the effluents are first allowed to stand for settlement and are then passed through the Adams machine, the subsequent separators can be run continuously day and night for a full week. The Adams machine is of the ordinary disc type of separator with the exception that the bowl hood has been extended and jets with leads placed in the periphery. It runs at about 6,000 r.p.m. with the result that any divided mud which does not separate out and pass through the jets will not choke up the subsequent separators. The Adams process was fully described in a paper read to the Institution of Chemical Engineers by Mr. B. A. Smith. The following is quoted from his paper :

" The effluents from the scouring plant, both the overflow from the side tanks and the discharge from the bowl bottoms, are passed through settling tanks, where the heavier particles of sand are precipitated. Such settlement may be continuous, the liquor flowing in at one end of the tank and overflowing from the other end. A small double screen filter is interposed to remove all vegetable and animal fibres. This is essential as small pieces of burr may become jammed in a jet while even single animal fibres can do considerable damage by cutting the apertures in the jets."

" From the filter, the liquor is passed into a small tank where it is heated to as high a temperature as possible without frothing, and from this tank is fed at the rate of about 700 gallons per hour into an Adams machine. In the machine the ordinary process of centrifugal separation occurs, while in addition the mud being the densest substance present, is thrown to the walls of the bowl, where it is washed out through the jets at the rate of about 110 gallons per hour. The greasy emulsion after passing through another small warming tank is separated in a standard purifying machine."

The disposal of the mother liquor and the liquor from the jets depends on the type of scouring employed. If the scourer employs suint and at the same time is washing such wools as skin or slipe wools which are very poor in suint, it is necessary to preserve all the suint possible. To do this, the liquor passing through the jets is returned to the original settling tank where the higher mud content upsets the equilibrium and causes further mud to precipitate. If the wool being scoured is rich in suint making materials, a proportion of the suint will have to be thrown out of the cycle and this could be done either by allowing the clean suint storage tank to overflow, or by passing the jet liquor away to waste and not returning it to the precipitation tanks. If the scourer is using a soap scour, it is advisable to freshen the scour periodically. The suggestion is therefore, that the amount of fresh soap solution which is added should balance the amount of liquor passing through the jets of the machine which could be run to waste. The mother liquor from the Adams machine would then be the clean soap solutions which could be returned for re-use. There are combers however who would be prejudiced against re-using the soap solutions. In such cases, both the liquor from the jets of the Adams machine and the mother liquor must be run to waste. Such liquors cannot be passed into the sewers, as the authorities will

not allow any effluent, even after being centrifuged to pass into their mains unless in an acid condition, therefore the only solution is to revert to the acid-cracking process, in order to dispose of the final liquors. It is claimed however by those using this type of centrifugal that the costs in the scouring department have been considerably reduced by the fact that the soap solutions can be returned for re-use.

The battage process and the subsequent aeration processes including the Merten and the Barber jet, are chiefly employed on the continent, where there is no difficulty with the laws controlling the disposal of trade waste. In the battage process, the effluent is kept agitated by continuous beating with hand paddles or bats, and the grease is caused to rise to the surface in a froth. This process has not been employed in England as it has an extremely low efficiency, the recovered grease amounting to about 25 per cent. of that present. The aeration process is somewhat similar to the battage process in that the liquors are subjected to violent agitation by a series of fine streams of air. The greasy foam is then washed, in order to remove as much soap as possible and is finally passed through an auto-clave.

The Merten's Process

This is a method for which great efficiency is claimed. The beater tanks deal with 1,650 gallons of effluent per hour and the paddles are kept in rotation by a small powered motor. The overflowing froth holds about 20 per cent. of grease and the discharged liquor 0·05 per cent. which can be regarded as being quite safe to run away into the drains. The efficiency claimed for this process is greater than either the Adams machine or the Barber jet, both of which claim to remove approximately 50 per cent. There is a difference however in the fact that both the Adams centrifugal and the Barber jet processes are dealing with liquors which probably have an initial grease content in the region of 2 per cent. to 3 per cent., whereas the Mertens beater tanks are dealing with liquors which contain less than 1 per cent. of grease. This remarkable efficiency is explained as being due to the rapid beating, which is accomplished by the power transmitted from the low powered motor. The subsidence and final melting of the grease is as in the Barber jet process, though a specially designed digester obviates much of the intermediate washing of the froth and facilitates the settling and draining off of the impurities. This process claims to produce a very high grade lanoline and is being worked at Verviers by a Belgian Company. It is doubtful though whether the Merten's process would show the same efficiency if working with liquors having a higher grease content.

The Barber Jet

The Barber Jet process claims that a more satisfactory separation of the grease from the effluent is obtained by combined physical and chemical means. In this process the effluent is run through catch pits—in which wool fibres and coarse sand are retained. The liquor is then pumped direct to a Barber Jet machine. The jet consists essentially of two concentric tubes fitting closely enough to allow only a very thin film of fluid to pass through the annulus. Air under pressure is also passed at the same time through another inlet into the inside of the inner tube, which has a number of perforations. The suspension of grease in water passes at a high velocity through the annulus, while five jets of air are forced into this film creating an intimate mixture of grease, water and air, tending to coalesce the particles of grease and so separate it from the water-phase. The emergent film then impinges upon an abutment below the jet boxes. It is found that under these conditions most colloidal materials coagulate to give conglomerate masses. This principle is the basis of the Barber Jet process as applied to the recovery of colloids.

This partially separated grease and water issuing from the jet is forced through a complete battery of jets, when a good separation is obtained. The floating grease is removed from the surface of the water in the last compartment. The

grease—in the form of a thick foam—is washed with water to remove traces of dirt and soap and conducted to a tank where the foam of grease receives a final water spray and is then boiled with water. The grease and water mixture is then pumped to a battery of continuous autoclaves, where it is maintained at a temperature of 120° C. to 130° C. Separation is assisted by a series of plates (alternate plates being perforated) set in the feed tube which is situated axially in the autoclave. The grease and liquor mixture is fed in at the bottom, being forced to take a zig-zag path through the plates in the feed tube, and overflows into an annulus and up again into the main body of the autoclave where the grease and water are removed separately. The outlets are controlled by automatic valves. By distillation products are obtained which are of great interest to the industries, marketed under the name of "Cebacols," As by-products the distillation plant also produces various grades of pitch ranging from a hard jet black to a medium soft brown.

The Solvent Process

The solvent extraction method is usually worked in conjunction with the scouring of wools by means of solvents. The wool is subjected to the action of an organic solvent which removes the grease, dirt, etc. The solvent liquor is then washed with warm water to remove mineral matter and distilled to recover the solvent, leaving the grease behind.

Methods for cleansing wool by means of solvents have never become popular in England, although various solvents and various different methods have been tried on the continent for the past fifty years. Those using solvents have always claimed that solvent scoured wool gives a much softer handle, and has better spinning properties than wool which has undergone the soap and alkali scour treatment. Opinions on this point however, are by no means unanimous, for the soap scourer argues that the heat required to remove all traces of solvent from the cleaned wool does more harm than the action of soap and alkali in the ordinary wet process of scouring.

Modern methods are very much improved and new types of solvents are being continually tested. One process which is in use at the present time on the continent, employs ethyl chloride. It is claimed that by the use of this solvent, wool can be degreased at half the present cost and that the gain of wool is more than 1 per cent. There is another solvent scouring process which is in use on the continent at the present time in which pure benzene is used. The wool is first de-suinted by water at 25° to 30° C., and after being dried in a vacuum, it is brought into contact with pure benzene at a temperature of 40° to 42° C. After degreasing, the benzene retained by the wool is distilled off under high vacuum by heat while the final purification of the wool is completed by running water at a low tempreature. For this system it is claimed that the wool does not felt so readily, spins to finer counts, and gives less waste in combing. The loss of solvent is said to be not more than 1 per cent. of the weight of wool treated, whilst the danger from explosion is reduced considerably by working at low pressure. The wool is not left harsh or brittle as about 0·6 per cent. of grease is left adhering to the fibres.

The mixture of grease and benzene from the degreasing process is run through a charcoal filter where the dirt, slime and the smell are removed. It is then passed through a calcium chloride filter to remove water and finally the benzene is distilled for further use, leaving a neutral grease of good quality, low acidity and a colour which comes near to that of commercial lanolines. Another big advantage claimed is that there is no effluent, since the solvent is passed direct to the recovery plant and the bulk is regained for further use. The efficiency of such methods is extremely high, being, according to statistics, from 90 to 93 per cent., while the expenses are comparatively low as most of the costs can be charged against the scouring plant and not to the grease recovery plant. Present types of scouring plant would have to be modified considerably but they claim a further

saving in that labour costs for bowl minders and feeders and the costs for motive power would also be reduced by half.

The solvent processes have their drawbacks, for insurance companies' premiums would be higher on account of the added danger from explosion. There is also the harmful effect on the health of the workpeople to be considered; this is often a serious matter where non-inflammable solvents are used. The dangers seem to outweigh the numerous advantages, for very few people in this country have taken any interest in solvent scouring. The solvent process may ultimately prove to be the ideal method of scouring when both its safety and its efficiency can be guaranteed. It would undoubtedly provide a very satisfactory solution to the effluent problem and allow the comber to put on the market a grease far superior to the present brown Yorkshire grease.

In reviewing the different methods of treating wool scouring effluents, it is interesting to know how the products obtained by these varying treatments are absorbed by the different industries. The brown grease from the magma or acid-cracking process varies in character according to its source, Merino wools yielding a much softer grease than the cross-bred types. Knowledge of its chemistry is still far from complete owing to its complex nature. Acids and alcohols are present, but all tests prove the absence of glycerol. Cerotic, stearic, palmitic and myristic acids have been detected in the grease, whilst the non-saponifiable fraction contains cholesterol, iso-cholesterol, cetyl alcohol and ceryl alcohol.

The major portion of the crude grease is destructively distilled, products of great variety being obtained. The stills are heated with free fire until all the moisture has been driven off and super-heated steam is then applied. The first product of this distillation is a light oil known as spirit oil. This is followed by a pale yellow product known as first distilled grease. The next fraction is green oil which is sometimes used for coarse lubricating greases, but is nearly always returned to the still with the next batch of grease. Finally, the distillate comes over as a thick oil. The residue from the still is a pitch, which is used as a lubricant for the necks of hot rollers and as an insulator for electrical cables.

The first distilled grease is usually allowed to seed or crystallise and is then subjected to pressure in order to obtain a liquid oleine and a solid stearine. The oleine that exudes from the crystallised cake before pressing is usually sold as No. 1 Oil. These oleines are chiefly used in the heavy woollen trade though a small amount is used in the manufacture of lubricating greases. It is useless for soap making on account of the large percentage of unsaponifiables that it contains. The stearines are chiefly used in the rubber industry and in the manufacture of polishes whilst the spirit oils, when not returned for redistillation, find a limited use in making dark varnishes and in the manufacture of bricks.

A considerable amount of brown grease from acid cracking is used in the manufacture of lanoline. The soap and fatty acids are separated and the unsaponifiable portion containing the sterols and the alcohols is bleached to give the lanoline of commerce, and the super pharmaceutical grade. The uses of lanoline are increasing every year, for in addition to being used as a base for ointments and salves, the pharmaceutical grades are used in the manufacture of cosmetics and medical plasters. The pharmaceutical lanoline must be of a very pale colour and have a free fatty acid content of not more than 0·2 per cent., whilst the commercial lanoline varies considerably in colour and free fatty acid content, the free fatty acid content sometimes being as high as 2 to 3 per cent. Large quantities of commercial lanoline are used in the manufacture of anti-rust paints and solutions,and leather dressing compounds. It is also used for superfatting toilet soaps, processing rubber, for blending with oils and greases to increase their viscosity and as a foam breaker in the sugar beet industry.

Lanoline is extremely hygroscopic and this characteristic enables the manufacturer of hydrous lanoline to incorporate up to 60 per cent. of water with the commercial anhydrous grades, giving the white creamy lanoline usually sold in tubes.

Not long ago an article appeared in the *Lancet* by Dr. Twort, the pathologist to the Manchester Committee on Cancer Research, on the prevention of cancer and tar dermatitis by the use of a protective composed of lanoline and olive oil. It has been proved that cancer and tar dermatitis are often caused by contact with mineral oils. Dr. Twort has directed his experiments towards finding a means of prevention, and to reducing industrial risks to a minimum. A substantial measure of success has attended his efforts and he has brought them up to date in a report of interest to textile people. He suggests that the more fully hydrogenated an oil, the less is its carcinogenic activity. As a protective measure, it was found that a mixture of anhydrous lanoline and olive oil was remarkably good, numerous experiments having failed to reveal any other ointment of similar efficacy. He recommends the smearing of exposed parts with this mixture of lanoline and olive oil before commencing work. The practical utility of lanoline has been tested by a large oil company during recent years and they gave a very favourable report on its use.

The dark brown fatty acids which are separated from the crude brown grease in the manufacture of lanoline have many uses. From the major portion, oleines and stearines are obtained by distillation, whilst a considerable amount is used in rope batching and for the lubrication of jute, hemp and sisal fibres. It is also used in the manufacture of cheap axle box greases and low grade lubricants.

The neutral greases obtained from the centrifugal processes are applied in various ways in addition to those already mentioned. The centrifuged grease usually contains from 1·5 to 4 per cent. of free fatty acid as against the 15 to 20 per cent. free fatty acid content of the brown grease from the acid cracking processes. The colour is also very much paler than the brown grease, so much so, that it quickly reacts to bleaching agents to give a good grade lanoline. It is used to a large extent in America for the manufacture of lithographic and multigraphic inks, typewriting inks, carbon papers, calico printing inks and ordinary printing inks. It is also used as a special neutral lubricant for valves, taps, wire drawing and steel cutting, as a water proofing material, in shoe polishes and in varnishes for colouring and water proofing electric bulbs. The centrifuged greases are largely employed in the distillation of the higher wool fat alcohols, as they contain a much higher percentage of these bodies.

Barber Jet Distillates

The grease obtained from the Barber Jet process is of a thick, smooth consistency. Most of this grease, particularly in France, is used for the non-destructive distillation of the higher wool fat alcohols which constitute the alcohol components of neutral wool fat and are known as wool waxes. In this method of distillation the fatty acids are left behind in the pitch. Six distinct distillates are obtained. These waxes are not oxidisable and will not go rancid, nor do they become resinous. Wool wax is a very suitable ingredient as a dispersant in the oil blending trade.

Oxy-cholesterine finds a large market in the cosmetic industry as an absorption base, a mixture containing 5 parts of this wax to 95 parts petroleum jelly, will absorb up to 230 parts of water. If mixed with lanoline it will absorb ten times its weight of water to give a fine almost snow-white cream, which is suitable for cold creams and has the soothing and emollient properties of the latter.

Another product of this distillation is a fatty alcohol which can be sulphonated very easily. The sulphonated fatty alcohols are employed in making first-class shaving powders and shampoos and are rapidly being recognised for their remarkable properties in scouring and bleaching of wool and worsted yarns. They possess excellent solvent and lathering properties, stability and lime resisting properties.

The chief problem at the moment appears to be the exploitation of the new products and anxiety as to the capacity of the different industries to absorb these products. One of the arguments in favour of the use of the sulphonated fatty alcohols, is that wool or any other fibre or material can be scoured with better results and that the pH safety zone from pH5 to pH8 is not exceeded. Against this is their present cost which makes their use almost prohibitive.

In the past it has been argued that owing to the limited market, wool grease produced by ordinary methods and that from special processes differed so little in selling prices that the expenditure necessary to modify plant was unjustified. This is chiefly the reason for the lack of progress in extracting process. Happily, the position is being rapidly reversed, partly due to the new markets that have been created during the past few years and partly through the artificial boom caused by the re-arming of Europe. At the present time it is doubtful if there is a comber in Bradford who holds any stock of wool grease.

The sud-cake produced in the acid process by hot pressing, is the only by-product for which there is no market to-day. Prior to devaluation of the franc, most of the sud-cake made in Bradford was sold in France. It proved an ideal way of importing grease and avoiding the tariff. The sud-cake contains from 14 per cent. to 20 per cent. of grease. The cheapness of solvents on the continent permitted the profitable degreasing of the cake. The degreased cake makes an excellent base for artificial manures, owing to its high nitrogen content.

Most combers are now tipping their sud-cake, for it is difficult to dispose of as a manure owing to the amount of grease that it contains. The corporation sewage works have overcome the grease content difficulty by piling the sud-cake, while it is still hot from the presses, in the form of sugar loaves. These sugar loaves are allowed to stand from ten to twelve months, the interior of the loaf retaining its heat and allowing the soft grease slowly to find its way to the base of the loaf. On testing the sud-cake after standing over this period, the grease-content is found to be as low as 4 per cent. The partly degreased cake is then ground and sold as manure, for it is found that the remaining 4 per cent. of grease does not in any way choke the land.

There is still a lot of work to be done towards finding the most efficient and economical method of recovering the grease from the effluent and its subsequent treatment, but there is no doubt that advance has been made. Wool grease recovery will not become a really valuable asset to the wool industries until its chemistry has been more fully investigated and the economical separation of its constituents becomes a financial proposition.

Reviews

Methodik und Anwendungsmoglichkeit der Zeitstudie in der Textilindustrie. By Dr. Ing. P. Bergfeld. Published by VDI-Verlag G.m.b.H., Berlin. (84 pages, Price 4.50 R.M.)

In this book, " The Theory of a Method and its Applications to Time Studies in the Textile Industry," the author gives a detailed report of time studies carried out during the years 1929-33 at the instigation of the German Federation of Plush and Velvet Manufacturers. Shortly after the war the German Government established a Committee " Refa " to make detailed investigations into time studies and costing in the metal industries from (*a*) Technical, (*b*) Organisation, and (*c*) Economic points of view, with a view to standardising prices, methods of production and wages. Dr. Ing. Bergfeld has applied these methods to his own investigations.

Two American systems—the Taylor and Bedaux—have already been used to carry out time studies in the Textile Industries, but the Author, in discussing these and comparing them with his own system based on " Refa," points out that the investigations are not so comprehensive or detailed. By applying the " Refa " system to the Metal industries, an accuracy of 3 to 5 per cent. has been obtained, and very careful and repeated tests are described which have as their object the attainment of the same accuracy in textiles. The studies begin with

winding and are carried through beaming, weaving, dyeing, printing and other finishing processes.

The detail and thoroughness with which these studies are carried out may be gathered from an example on " Winding " where the time is measured under ten different headings as follows :—

Preparing and arranging the Hanks.
Laying the Hanks on the Haspel and tying up the threads.
Changing the full bobbin.
Movement of the operator about the machine.
Attention to the machine itself whilst running.
Piecing broken ends (Sub-divided according to cause).
Bringing material.
Freeing tangled and twisted threads.
Small repairs.
Overlooking, etc.

For measuring the actual times taken, a twelve point recorder is used, a synchronized clockwork moving a chart on which the 12 pens are operated as stop watches. The methods of analysing the results are explained, logs of actual tests in the form of 10 tables being given. By means of these, the author is able to estimate the times required in similar processes for various qualities of material and sizes of machines, and to fix standard working times and costs for the processes under consideration.

It is claimed at the outset that no such minute investigation into production time in the textile industry has yet been made, and a study of the methods so carefully explained by the author should enable anyone interested in this subject to apply the system to his own branch of the Industry. The treatise is concisely written but no point is left unexplained. R.H.F.

Additions to the Library

Handbook of " Amoa " products and " Amoa " Emulsions. Amoa Chemical Co.

This is an attractively printed booklet prefaced by a readable account of the physico-chemical processes of emulsification. Methods of preparing emulsions are appended. Formulæ of interest to dyers, finishers, etc. for wetting agents, dulling agents, proofing agents and so on are given. T.

Dr. H. A. Zwynenberg. Alexander Numan, in het byzonder zyn invloed op de Nederlandsche Schapenfokkery. Utrecht, 1925, 193 pp.

Historical review of the experiments, conducted by Numan between 1830 and 1852 to cross-breed Disley and New-Leicester sheep with the original Dutch races, with reports about the improvement in the spinning properties of the wool. (Presented by Mr. J. F. Straatman.) J.F.S.

General Items and Reports

BRITISH INDUSTRIES FAIR.

Textiles Exhibition at the White City

An Exhibition of Textiles in connection with the British Industries Fair at the White City, Shepherd's Bush, London, opened on 15th February, 1937. Two reports on the fabrics shown have been prepared at the request of the Publications Committee and are hereunder presented. It is to be understood that any opinions expressed are those of the contributors and not necessarily those of this Institute. The reports cover Cotton and Artificial Silk goods, and Woollen and Worsted fabrics.

Cotton, Flax and Artificial Silk Materials.

Comparing this exhibition with the one held twelve months ago, a pleasing feature was the greater interest which the Manchester firms have taken in the display of their many and varied productions. Collectively, the exhibition of Lancashire made fabrics was unique in scope and variety, extending from those fabrics produced essentially for export, to almost every type of cloth used for domestic purposes in this country.

There are no outstandingly new features to record in yarn constructions, nor in the details of the weaves of the fabrics in the exhibition as a whole. There is, however, a notable absence of the rather crude rectangular and severely abstract forms of designs, both printed and woven, which have been popular during recent years. Vigorous applications of colour were exceptional. In this respect the fabrics shown were subdued, though there was no suggestion of dullness. Rayon continues to hold the most prominent place in light dress goods and as effect yarns in soft furnishings. Yet there is evidence of its limitations in many fields of fabric construction and the material seems to be entering on a new phase of its activity in evolving new effects.

Another point of general interest is provided by the furniture trades section where upholstering fabrics can be judged in actual use. There is scope for close co-operation between the primitive designer and the fabric manufacturer. In both design and quality the fabrics appearing on the furniture exhibits were not to be compared with the best examples shown in the textile section.

The high standards attained by the British manufacturers of casement and soft furnishing fabrics have been maintained, though changes in style and design are noticeable. The fabrics appear to group themselves into three fundamental classes. Rayon warps, set end and end in two colours, with cotton wefts of various colours, either in pick and pick order or in the form of bars across the fabric, are the bases on which beautiful tapestries are produced. The second class, and one which has increased in importance, is found to consist of Damask materials with good " period " or historic designs, along with excellent new figure effects. These fabrics are made in all silk, rayon warp and cotton weft, and flax warp and rayon weft. An excellent furniture covering material is made by the clever combination of wool, flax and rayon, the first two providing the required mechanical properties of the cloth and the last the ornamentation. The third class is distinctive in having embossed decorative effects produced either by weaving or by embroidery stitching, using an additional backing fabric for the purpose. Glazed chintz fabrics appear in this class. Many attractive designs in casements consist of relatively small weave effects such as can be produced on dobby looms. A design worthy of special notice is named " Cirrus." It is a striking reproduction of the cirrus cloud formation. Shadow prints woven with cotton knop weft and also with coarse lightly folded cotton yarns produce some very effective fabrics. Cheap cloths, with the appearance of looped pile moquettes, but actually made from low grade cotton yarns have been extensively applied in the furniture on exhibition. The imitation moquette effect is produced by the use of coarse cotton wefts giving a ribbed appearance, together with printed warps or multi-coloured warps of finer cotton counts. These fabrics contrast violently with best examples of upholstery fabrics shown in the fabrics section. There is surely no reason why the furniture manufacturers' taste should be poorer when applied to fabrics than when dealing with wood and other materials.

An unusual application of old designs to new purposes was seen in carpets of Tartan Check. They had the appearance of highly magnified pieces of Scotch plaid or scarf. Another striking design for a carpet consisted of monkeys climbing up the bars of a cage. This idea had come straight from the Zoological Gardens, and it would be difficult to find such a floor covering another home.

The Manchester dress goods section contained both printed and woven effects, using all-cotton, cotton and rayon, full rayon, and spun rayon yarns. Slub and knop yarns were used with discretion to make effective backgrounds on these light textures, many of which were figured by printing. The section provided the brightest colour display of the exhibition, yet the individual fabrics were not in themselves over-coloured. The massed colour effects were the result of splendid grouping of the exhibits. There was an almost complete absence of freak block and line designs, and only a few of the fabrics have a Coronation

background. The joint Committee of Cotton Trades Organisation made a special display of cotton fabrics for the overseas markets. Materials appropriate for Central and South America, Near and Middle East, Africa, India and Far East were shown, together with examples of practically all the standard types of cotton fabrics for our own domestic use. Such a very wide range of goods could well occupy considerably greater space. The Lancashire Indian Cotton Committee gave ample evidence of the variety of uses to which Lancashire spinners and manufacturers are applying this raw material, the consumption of which has increased considerably during the last year or so. The yarns and fabrics were the collective contribution of many individual firms. Pre-shrinking treatment on the finishing of cotton piece goods is evidently becoming standard trade practice for a widening range of fabrics. A novel towel cloth having terry-pile on one side, and huck-a-back weave on the other side, stands out as a new venture in cloth construction. Remarkable developments in the production of all-cotton bed spreads were to be seen. Here, new types of yarns and thread settings have been wedded to the older weave systems. Folk-weave styles of designs on excellent colour schemes and fabric with good weaving qualities, yet soft to handle, are the result. Printed effects on pique weaves show another application of a well-known cotton structure. The small bird's-eye design has been enlarged, and converted from a dress-skirt fabric into a soft-handling summer dress material. The cloque effects for dress goods, chiefly produced from rayon yarns are another application of the same nature.

The leading manufacturers of rayon and artificial silk yarns had special displays of the extensive uses of these materials. In the woven fabrics, hard-twisted yarns for crape effects appear to be giving place to a more liberal use of fancy doubled yarns for obtaining roughened effects. A new development in the use of "fibro" is the introduction of a small percentage in woollen and worsted suitings, the amount being so small as not to affect materially the qualities of the wool fibre for this purpose. The blending is done in the fibre or slubbing state and the fabrics are woven in the material colour of the scoured wool. Later, the material is piece-dyed to any shade required, the fibro resisting the action of the dye bath.

Remarkable effects are obtained, which to all appearances are the products of the standard system of blending dyed fibres or slubbings. Check suitings, etc., can be produced by piece dyeing to any colour or shade the buyer requires.

The demonstration of the "Rigmel" process drew much attention. The machine shown is that in which the effects due to the stretching of the warp, which takes place in the various stages of manufacture, is counteracted by forcing the picks closer together. The cloth put through the machine had received prior treatment as regards shrinkage in the weft direction. A more complicated type of machine is necessary for this purpose.

An exhibit of considerable interest consisted of samples of "ionised" oils with materials to which they are applied. These oils are claimed to be specially suitable for batching and processing flax, giving whiter, softer and less creasable fabrics. They are applicable also to fabrics containing rayon as sizing agents for eliminating or reducing cannage.

The possible applications of oiled silk were shown in one display to be very extensive. Agreeable effects were obtained by the use of these fabrics for casement cloths. Quilting on to light cotton cloth bases results in cloths for which many uses can easily be found.

J. Read.

THE WOOLLEN AND WORSTED SECTION

The outstanding feature this year is the influence of the forthcoming Coronation of their Majesties King George VI and Queen Elizabeth which is apparent throughout the fair and in the case of woollen and worsted cloths this is shown mainly from the point of view of colour and combinations of colour and especially in cloths for men's wear.

Considering only the woollen and worsted sections the exhibits this year are disappointing. Novelties in fabrics for ladies' wear are conspicuous by their absence and the definite influence of the Coronation on men's suitings makes these somewhat monotonous as there is a lack of variety. Judging by the exhibits, greater attention is being given by manufacturers to fabrics for sports wear and there would appear to be no limits to the liberty given to designers in producing cloths for this purpose. Bright coloured grounds in solid colour or in a combination of colours and with bold overchecks are much in evidence.

Men's Wear.

The trend of colour and design in men's worsted suitings is very definite indeed. The most popular styles are shown in yarn dyed mixture grounds for the better qualities and in piece dyed grounds for medium qualities. The ground is 2/2 twill serge either plain twill or plain twill and reverse to give a herringbone effect. The "Coronation Stripes" on these grounds are a development of chalk stripes. They consist of 2, 3 or 4 ends of silk, mercerized cotton or staple fibre and the stripes are usually alternated in colour at intervals of approximately $\frac{3}{4}$ in. Red and blue, red and gold, blue and gold are the principal striping colours and these are shown in varying degrees of brightness, the richer and fuller colours being in the better qualities. The ground colours are in various shades of Coronation blue, blue grey and grey and a new shade "Petrel" which may be described as a "smokey green blue." A strong feature in yarn dyed worsted suitings is the introduction of line overchecks in red, blue or other rich colours on grey, blue grey and blue grounds.

In yarn dyed mixture flannels in various shades of grey, blue, green and some lovat shades there are both stripe and check designs. The stripes are very neat and in one chosen by His Majesty King George VI the stripes are in silk and consist of black and white striping threads on a grey mixture ground. The principal stripe contains about eight ends of each colour, dressed end and end and is crammed and woven in straight twill; the secondary features are smaller stripes woven reverse twill. The repeat is about $1\frac{1}{2}$ inches. The check designs are simple line overchecks in red, blue or white and measuring about 2 inches across and $2\frac{1}{2}$ inches in length. Smart mixture suitings are shown in 2/2 twill plain grounds with pin stripes of $1\frac{1}{4}$ repeat. The stripe consists of one white end, bordered on each side with a black end. Exhibits are again made of suitings made from a blend of wool and staple fibre rayon. When wool dyed, these give the appearance of a mixture suiting and have the advantage that ground colours need not be chosen until the cloth is actually woven.

All wool tartan check linings are shown and these are waterproofed and intended for use as linings in gabardines, coverts and similar waterproof garments.

There is one yarn dyed suiting cloth shown in a variety of colours which consists of end and end colour and colour throughout the warp and gives a low angle chevron design repeating on $1\frac{1}{2}$ inches. Some of the end and end combinations are fawn and black, grey and blue and grey and black.

In overcoatings for men's wear the effects are mainly very bright and designs distinctly bolder. One example is a very coarse cloth woven with thick counts of loosely twisted yarn in a broad herringbone weave and with an overcheck of bright colour twisted with the ground yarn. Green ground with red overcheck and blue ground with red overcheck are outstanding colours and the overchecks are about 4 inches by 5 inches and made with the overcheck colour twisted with the ground shade. Other overcoatings are black and white check grounds 4 by 4, 8 by 8, etc., with bold overchecks 5 inches by 7 inches introduced by increasing the number of ends and picks in each colour and also introducing red, blue, etc., into the overcheck.

For sports wear very bright coloured tweeds are shown in a varied selection of checks and colours. In some cases plain twill grounds are shown in green, blue, natural and lovat shades, but in most cases these have strong contrasting line overchecks about 3 inches by 4 inches. Where grounds are checked the

colours are remarkable in the brightness and clash of contrasting colours such as lemon, red and white, grey, bright blue and brick, and many others too numerous to mention. Ski-wear is featured by a plain 2/2 twill serge in white, bottle green, navy and black, also in a heavy delaine in bold checks in black and white. Flannels for suits are in green with red line overchecks, navy with white overchecks and lovat with red overcheck.

Hosiery.

There is one very interesting feature shown in pullovers for men's wear with golf hose to match and is composed of a variety of multi-coloured yarn effects knitted in an " off stitch." There is a base or ground colour of natural fawns, greys or drabs, etc., and the multi-colour effect is obtained by small knops in a large variety of shades. To give one example only, this is composed of fawn ground with knops in lemon, apricot, gold, brick, violet, black and turquoise and the resultant effect is most pleasing, mainly due to the smallness of the knops and their even distribution. In golf hose there are also pastel shades of green, blue, fawn and grey with boucle yarn containing tone and tone knops.

Scarves.

These are shown in the brightest of colours in plain and check. A scarf made from pure cashmere was shown in Coronation red and Coronation blue, also block checks of these colours divided by white. In saxony scarves a large range of authentic tartans are in evidence.

Ladies' Wear.

As previously mentioned there are very few exhibits of fabrics for ladies' wear in woollen and worsted and these do not show any particularly new features. The whole gamut of possible novelties has been passed through so rapidly during recent years that a return is foreshadowed to plainer types of clothes which have not been in evidence for a long time. A few tweeds are shown but these are similar to previous seasons in knops and slubs, either tone and tone or in multi colour. One effective cloth for dresses was composed of half an inch block check wool, and wool and angora with an overcheck of spiral slub. There are tweed effects made with wool and staple fibre, and in one cloth the fibre was left on the surface to give a kemp effect.

On one stand, a woollen cloth is displayed woven on an orlean ground and an extra weft of thick count is woven in Jacquard effects and then cut on the face of the cloth removing all the long floats and leaving tufted ends. One heavy face cloth for mantlings is shown and this is composed of wool and mohair and is in a drawn finish. An interesting tweed is made with white woollen warp and coloured slub weft. The slubs are irregular in size and shape and the result gives a ripple effect.

For country wear Scotch tweeds are in evidence in grey, soft blues, green greys and blue greys. These are decorated with multi-coloured slubs or knops in bright colours. One example on a grey ground had knops of brick, blue, brown, green, maroon and lavender. Either for men's or women's wear, browns are not in evidence.

Carpets.

In this section there are two new features. One interesting exhibit showed carpets woven in a variety of standard tartans in which are the Gordon, McPherson, Royal Stewart, McDonald, Antique Cameron, Sinclair and McLaughton. As one can imagine they are very striking and colourful and we are not concerned here with their utility or harmonious blending with other furnishings. The other novelty which attracted attention is a show of pale pastel ground shades in fawn, green, blue, rose, etc., and the only decoration was a black line effect in simple design sketched in one corner or across the carpet from corner to corner.

The influence of the Coronation is in evidence with plain carpets which are shown in four rich shades of gold, blue, red and green. F. HAIGH.

THE JOURNAL OF THE

TEXTILE INSTITUTE

Vol. XXVIII | MARCH 1937 | No. 3

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

Annual Meeting of the Institute, 1937

This Meeting, at which it is hoped a good attendance will be secured, will be held at Headquarters on Wednesday, April 14th, at 3 p.m. The Annual Report of Council, with the Balance Sheet and Accounts, will be presented. Copies of these documents are included in this issue for the information of members. At the Annual Meeting, Mr. W. Turner, J.P., of Bradford, will retire from the office of President and will propose the election of Mr. John Crompton, O.B.E., of Ansdell, Lytham, to that office. To the office of Vice-President, in which there are three vacancies, Council have nominated Messrs. Henry Binns, Frank Wright, and S. E. Ward, and, in the absence of other nominations, these gentlemen will be declared elected. A Ballot will be conducted for the ten vacancies on the Council and for this purpose a Ballot form and envelope have been inserted in this issue for the use of all members entitled to vote. The number of votes recorded in previous years has not been regarded as satisfactory and it is hoped that every member, who can, will record his vote on this occasion. A Notice of the Meeting is also included in this issue.

Council Meeting, March, 1937

At the monthly meeting of Council, reference was made to the absence of Mr. Frank Wright, a Vice-President, on account of ill-health. Mr. Wright had been operated upon successfully and good wishes were expressed for his speedy and complete recovery. Details of the Annual Meeting, given above, were reported and the requisite authority to conduct a Ballot for election of Council members was given.

In regard to the Annual Conference at Southport in June next it was reported that Sir Harold Hartley, a Vice-President of the London, Midland and Scottish Railway Company, had accepted invitation to deliver the Annual Mather Lecture and that Sir Frederick Marquis had accepted invitation as chief guest at the Conference Banquet. Provisional reservation of accommodation has been made at the Prince of Wales Hotel, Southport, which will be the Headquarters of the

Conference. A Preliminary Announcement relating to this important event in the Institute Calendar is in course of preparation and will be issued shortly after Easter. Meanwhile members are asked to record the dates—June 9th, 10th and 11th—and to use every endeavour to attend.

At the invitation of the City & Guilds of London Institute a representative on their Advisory Committee on Textile Printing was appointed—Mr. W. Kershaw being re-nominated, and thanked for his previous services. Two representatives of the Institute were invited by the Corporation of Manchester to take part in the civic procession on the occasion of the Coronation. Mr. Frank Nasmith, Hon. Secretary, accepted nomination in one instance and agreed to arrange for the second representative.

University Appointments

The authorities of Leeds University announce that :—

J. B. Speakman, D.Sc., F.I.C., F.T.I., Warner Medallist, Lecturer in Textile Chemistry in the University, has been appointed Reader in Textile Chemistry, and that—

W. T. Astbury, Sc.D., M.A., F.Inst.P., Warner Medallist, Lecturer in Textile Physics in the University, has been appointed Reader in Textile Physics.

Employment Register

The following announcements are taken from entries in our Register of members whose services are on offer. Employers may obtain full particulars on application :—

No. 130—Young man, Nottingham University College Diploma in Textiles and practical experience in all branches of Hosiery dyeing and finishing, including bleaching by all processes, desires position as Hosiery Dyer or Dye Works Manager. Age, 39 years.

No. 153—Desires position as Textile Technologist or Technical Advisor or Responsible or Managerial post to Private Firm or Public Body. Fifteen years' experience in Hosiery Trade. Five years at Public Testing House, and experience in lecturing. Knowledge of Costing, Factory Management, Past Examiner. A.T.I. Fellow of Royal Microscopical Society. Age, 34 years. Prepared to go abroad.

No. 154—Requires position in Pure Silk dyeing works, or Manufacture Departmental Manager. Nottingham University College Diploma in Textiles. City & Guilds Final Grade Certificates in Hosiery. Age, 24 years.

No. 155—Requires position as Carder, Assistant Manager or Research or Experimental Department of Rayon Industry. Full Technological Certificate. Prepared to go abroad. Fourteen years' experience as Carder and two years as Manager. Age, 39 years.

No. 156—A.T.I. requires position as Designer Manager, Designer Salesman or Technical Manager in large concern. City & Guilds 1st Class Final in Woollen Spinning. Leeds University Diploma in Textiles. Nine years' teaching experience in Textile Design and Colour. Study also Textile Finishing and Woollen Spinning. Age, 38 years.

No. 157—Young man, requires position as Assistant Manager of Silk Throwing Mill or similar position in Silk Manufacturing. City & Guilds Final in Silk Manufacture and Drapers Scholarship. Ten years' experience in Manufacturing. Two years Assistant Manager in Silk Throwing Mill. Age, 25 years.

Institute Membership

At the March meeting of Council, the following were elected to Membership of the Institute :—

Ordinary.

J. W. Brown, 18-20, Martin Place, Sydney, N.S.W., Australia (Textile Chemist and Consultant).

A. M. Paterson, 114, Rose Street, Dunfermline (Textile Analyst).

U. G. Puthli, 1/36, Rangari Building, Delisle Road, Bombay 13, India (Secretary, Toyo Podar Cotton Mills, Ltd.).

Junior.

F. A. Ford, 168, Mile End Lane, Stockport (Manager, Cotton Mill).

J. Barnes, Willow Grange, Rishton, Lancs. (Textile Chemist).

COUNCIL'S ANNUAL REPORT, BALANCE SHEET AND ACCOUNTS FOR 1936

To be presented at the ANNUAL GENERAL MEETING,
Wednesday, 14th April, 1937

COUNCIL'S ANNUAL REPORT

The outstanding new development in the activities of the Institute during 1936 is the formation of a committee to inquire into the Unification of Methods of Testing in the field of Textiles. In this important work the Institute has received a general mandate from a large number of interested bodies and will co-operate freely with the British Standards Institution. The past year is also memorable by reason of exceptional staff changes. After twenty-one years service, Mr. J. D. Athey was compelled through a severe breakdown in health to tender his resignation, which was accepted with much regret. To mark their appreciation of his services, the Council has elected Mr. Athey an Honorary Life-member of the Institute and voted him a pension. This has been supplemented by a testimonial Fund to which a large number of members made generous contributions.

The Balance Sheet and Accounts for 1936

Revenue Account: 1936 was an unusual year, in that staff changes, the resignation of the General Secretary, and the appointment of a Technical Editor, were made, and the Annual Conference was held in London on a more ambitious basis than previously. In the Council's opinion, these additioms to expenditure have been justified. The increase in Library expenditure, is to be accounted for by the issue of a new catalogue, and the binding of Patents Journals, bringing the Institute's set up to date and complete.

The gross amount of income tax paid has been the same as for 1935, but as arrears for past years are now all cleared up, no refunds were received during the current year. A slight but gratifying increase in revenue, can be recorded from Membership Subscriptions.

Balance Sheet: When considering the position shown in this account, the increased expenditure on account of salaries, and Annual Conference, should be borne in mind. It should also be noted that £60 was left on deposit in order to keep this account open, and this sum might have been employed in reducing the Bank Overdraft. The interest paid on deposited funds, however, exceeds the overdraft charges, and on this account it is justifiable to leave money on deposit. It should also be noted that substantial additions to the furniture and fittings of the office, have been made, which are not expected to be repeated in 1937.

Under the circumstances described, the Finance Committee and Council, are satisfied with the Institute's financial position, and look forward confidently to a further improvement in 1937.

Schedule of Investments: This schedule when compared with that for 1935, indicates that the Institute's investments, though remaining at the same nominal figure, have slightly appreciated in value.

Journal Account: A slight falling off in advertisement revenue has to be recorded, but other sources of revenue show increases. On the expenditure side, printing charges have been reduced, but expenditure in other directions, has shown increase in details.

Crompton Prize Fund Scheme: The Competitions, conducted annually since the inauguration of this scheme, were not held in 1935. The balance brought forward was therefore larger than in previous years. During the current year, prizes were again offered and the balance of £68 carried forward will materially assist the competitions of 1937.

Foundation Fund: The revenue from this fund, is increased by the interest on Leeds Corporation Stock, purchased from £1000 legacy from the late R. J. H. Beanland, of Huddersfield. Otherwise, the revenue remains much the same as in 1935.

Scholarship Scheme: The third scholarship awarded by the Institute, is now held by Mr. J. Airey. The funds available are adequate for the third year of this scholarship, but it is not expected that a further award will be made in 1937.

The Annual Conference and Exhibition

London was chosen as the centre for the Annual Conference, and arrangements for a comprehensive and what proved to be a very successful event were made by a special Committee upon which the London Section Committee was represented. The Conference was the fifth of the series commenced in 1932, and centred round the general subject—

" The Production and Properties of Textile Fibres." Eleven papers were contributed and were printed in full in the July issue of the *Journal*. The Mather Lecture was delivered by Dr. Ernest Goulding lately of the Imperial Institute ; his subject being " Textile Fibres of Vegetable Origin : Forty years of Investigation at the Imperial Institute". At the Conference banquet the President, Mr. Wilfred Turner, J.P., of Bradford, occupied the chair and some two hundred guests and members were present. Sir Percy Ashley of the Board of Trade was the principal Speaker, and proposed the toast of " The Textile Institute". Institute Medals, awarded to Mr. J. E. Dalton and Mr. T. Morley, were presented during the evening. The Conference commenced with a reception by the Drapers' Chamber of Trade, and another reception was given by Imperial Chemical Industries Ltd. at their headquarters in Millbank. An Exhibition of Scientific Apparatus and devices was held during the Conference and was fully representative so far as exhibitors were concerned. A smaller exhibition of privately contributed apparatus was also arranged. Dr. Harry Moore, director of the Scientific Instruments Research Association opened the Exhibition and a good attendance was recorded throughout the three days exhibit. A Catalogue of the Exhibition was prepared and issued to all visitors. (Copies are still available.)

Publications Committee and *Journal* of the Institute

The work of this Committee has steadily progressed and the sources from which contributions have been received are as widespread as hitherto. The co-operation of the Research Associations continues to merit the full appreciation of all members not only in the work of *Journal* production but in the direction of help in Library matters and in answer to inquiries. The services of many referees are still given as freely as ever and no record of work would be complete without reference and thanks to these services.

The Conference issue—July, 1936—contained the papers contributed to the " London " Conference and forms a valuable record of the general subject upon which all the papers were based—" The Production and Properties of Textile Fibres". The changes in *Journal* staff made during the year, and referred to elsewhere, naturally affected the work of publication unavoidably holding up, for example, the issue of the annual Index.

The Selection Committee and Institute Diplomas

The volume of applications for the Diplomas of the Institute is steadily increasing, and the work of carefully scrutinising each application has been carried on continuously throughout the year. The Institute's Examination held in connection with the Associateship Diplomas was this year held in May—Part I on May 19th, and Part II on May 26th instead of in June as in previous years. The Examination was held simultaneously at Manchester, Bradford, Nottingham, Dundee, Cawnpore, Indore (C. India) and Hamilton (Ontario, Canada) with the following result :—Part I, 7 candidates (2 passed) ; Part II, 48 candidates (38 passed).

Applications for Institute Diplomas during 1936 totalled 88 (9 Fellowship and 79 Associateship) as against 60 in the previous year (11 Fellowship and 49 Associateship). The total number of applications since the inauguration in 1925 reached 932 (302 Fellowship and 630 Associateship).

A noteworthy piece of work by this Committee has been the recognition of certain degrees and certificates as " threshold " qualifications upon which candidates otherwise suitable can be admitted to Part II of the Institute's Examination. These Certificates include the Full Technological Certificates of the City and Guilds of London Institute in Dyeing and in Textile Printing, as well as Degrees and Diplomas of other Organisations in Colour Chemistry and Dyeing.

Institute Competitions : Textiles and Designs Committee

The work of this Committee has been affected materially by the decision reached in the previous year to change the date of entry for all Institute Competitions. Instead of requiring entries in the middle of the academic year, it was decided to call for such entries at the end of the schools' year, and this necessitated an interval of 18 months between the 1934 Competitions and those of 1936. Entries for the current year were well up to previous record and were as follows :—116 for 1936, as compared with 70 in 1934.

Adjudication was this year undertaken by specially appointed sub-committees and this speeded up the work considerably. It was also felt desirable to issue the Reference Collection of Fabrics at the beginning of the academic year. This meant the issue of two such albums in 1936. The work of compilation devolved on a small

sub-committee and was completed in time to issue the albums in October. Special thanks are recorded to the following firms for gifts of fabrics for the collection just issued: Messrs. J. Hall & Sons Ltd., Burgess Ledward & Co. Ltd., Whitworth and Mitchell Ltd., Horrockses Crewdson & Co. Ltd., Wm. Hollins & Co. Ltd., Barlow & Jones Ltd., Courtaulds Ltd., British Celanese Ltd., John Halliday & Sons Ltd., Old Bleach Linen Co. Ltd., Warner & Sons Ltd.

This Committee has now made arrangements for Competitions under the terms of the Beanland bequest. The late Mr. R. J. H. Beanland, of Clayton West, Huddersfield, left £1,000 to the Institute, the income from which is to be devoted to Competitions. Mr. Beanland expressed the wish that such Competitions should relate to the production of Fabrics mainly from worsted yarns. Two competitions have been set up and the conditions appertaining to each have been defined. These and revisions of conditions in other Competitions were embodied in the 1937 Prospectus which was issued to all Colleges and Schools interested in the Competitions schemes. The prize distribution in 1936 was very well attended, and was held at the Institute on Saturday, 24th October. Mr. John Crompton presided and the prizes were given away by Sir Thomas Barlow who afterwards delivered a very interesting speech on the training and employment of designers.

National Certificates in Textiles

The second year's experience of this scheme has now been completed and the Joint Committee of the Board of Education and the Textile Institute has reported on the period. This report records that participation by Colleges and Schools had proved satisfactory. 22 such organisations conducted 41 courses (2 being Interim Courses) and 192 candidates presented themselves for the Final Examinations; 146 Certificates being awarded.

Development Committee

This Committee only came into being at the end of 1935 and commenced work by a survey of Institute Membership and activities. Attention was directed to special Propaganda methods and during a concentration period of eight months several hundred firms were circulated and copies of the Institute's Journal sent when requested. In co-operation with the Library Committee, special arrangements were made to increase the hours of opening and these are more fully described below. The Institute's Prospectus has been revised and issued in a more compact and attractive form.

Library Facilities

This Institute service continues to develop. Each year more members avail themselves of the privilege of borrowing books and periodicals, but it must be said that the majority of members do not yet appear to realise the extent of the Library's activities. During 1936, in response to a suggestion from a member, the library was opened one night a week till 8.30 p.m. and one Saturday afternoon per month till 5.30 p.m., but the attendance did not justify a continuation of the arrangement. A fresh edition of the Library Catalogue has been printed and a copy sent to each member in Great Britain and Northern Ireland. A noteworthy addition to the library shelves during the past year has been seven bound typewritten volumes on "The Wool Textile Sphere", by the late Mr. G. F. Ashley of Bradford.

The Annual Meeting

This was held in Manchester on Wednesday, 22nd April, and a better attendance than usual can be recorded. Mr. Wilfred Turner, J.P., of Bradford, was re-elected President by a unanimous vote. Much satisfaction was expressed on his consenting to a further year of office. Messrs. W. Kershaw, F. Nasmith and W. H. Webb were elected Vice-Presidents, and during the year to fill vacancies caused by death; Mr. F. W. Barwick and Mr. F. Wright have also been elected Vice-Presidents. The newly-elected Council voted Mr. H. Jaques of Bradford, Chairman, and Mr. W. Kershaw, Manchester, Vice-Chairman, whilst Mr. Frank Nasmith and Mr. W. W. L. Lishman were re-elected Honorary Secretary and Treasurer respectively.

Unification of Testing Methods

Early in the year Council gave its consent to the publication in the *Journal* of a Memorandum of policy on this important subject. This document appeared in the February issue and reprints were sent to the principal organisations in the Textile Industries, both on the Manufacturing and Distribution sides. It was also sent to Testing and Conditioning Houses, to the Textile Research Associations and to various learned Societies and Government departments. General approbation was the keynote

of replies and comments, and on this basis the formation of a Standing Committee was felt to be justified. Such a Committee has been formally instituted, and is planning its activities carefully and with a view to the steady but sure development of a very important but long neglected field of work. Here again, the closest possible contact has been maintained with the Research Associations with whom it is intended to co-operate in every possible way.

Section Activities and other Events

In June a party of Agricultural students from Texas, U.S.A. was entertained to lunch at headquarters and met representatives of the Institute.

In October a visit of Midlands Section members was organised to the "Textile Recorder" Machinery and Accessories Exhibition at Leicester. They were entertained to tea by the Exhibition authorities, and Mr. Frank Nasmith delivered a short address on the Exhibition.

The usual Sectional activities have been pursued and lecture-cum-visit programmes have been arranged. To complete the roster of Section Honorary Secretaries, this office was instituted for the Lancashire Section, the first holder being Mr. Enos Lees, of Ashton.

The Midlands Section held its first Annual Dinner just before Christmas, and the occasion was made memorable by the good attendance and the presence of the President, Mr. Wilfred Turner, and the Hon. Secretary, Mr. Frank Nasmith.

The Federation of Textile Societies and Kindred Organisations held its Ninth Annual Meeting and Conference at Haslingden, as guests of the Local Textile Society. A thoroughly interesting programme was undertaken and the whole-hearted support afforded by the Haslingden Town Council was much appreciated.

Institute Staff and Premises

Owing to the serious illness of the General Secretary which began in November, 1935, the Staff had to bear unusual pressure of work during the year. Mr. Athey's resignation was received in May and Mr. Hugh L. Robinson, previously Editor of the *Journal*, was appointed General Secretary. Mr. W. J. Hall has joined the Staff as Technical Editor of the *Journal*. Miss D. Trippier, for over ten years on the clerical staff, has resigned on the occasion of her marriage.

Institute premises receive the constant supervision of the officers and staff, and several improvements and additions to equipment have been made throughout the year; a hot water supply and ventilating fans being among these additions.

Council and Committee Meetings

The following is a record of meetings during 1936:—Council, 10; Finance and General Purposes, 11; Selection, 7; Library, 1; Publications, 11; Scholarships, 1; Textiles and Designs, 6; Institute Development, 13; Conference, 5; Lancashire Section, 3; London Section, 3; Midlands Section, 2; Yorkshire Section, 1; Scottish Section, 2; Irish Section, 0. The total number for 1936 was 76 as against 69 in the previous year. In addition six sub-committees met for the consideration of special matters.

Section Meetings and Lectures

Seven meetings of the Lancashire Section (and one visit); eight of the Yorkshire Section; one of the Midlands Section (and five visits); two of the Scottish Section (and two visits); three of the London Section; and three of the Irish Section took place during 1936, at which papers were read and discussed. Social Evenings or Dinners were also held in certain Sections.

Membership

The membership list at the end of 1936—to be carried forward to 1937—was made up as follows: Honorary Members, 7; Life Members, 46; Ordinary Members, 1,360; Junior Members, 144; Total, 1,557, as against 1,526 at the end of 1935. Of the members at December 31st last, 183 had been admitted to the Fellowship and 351 to the Associateship.

The Council laments the loss by death during 1936 of many prominent members, including the following: E. Blackburn (North Wales), J. West Akam (London), T. E. Bingham (Manchester), S. B. Dalal (India), Col. B. P. Dobson (Ulverston), a Past-President, N. Fogg (Manchester), H. P. Greg (Styal), a Vice-President, H. Lee (Manchester), H. Mason (Germany), T. Morley (Leicester), a Vice-President and Institute Medallist, J. Smeaton (Manchester), C. F. Topham (Coventry) an Honorary Fellow, and H. N. Whalley (Rochdale).

The Textile Institute—Balance Sheet as on 31st December, 1936

Dr.

1935 £ s. d.	LIABILITIES.	£ s. d.	£ s. d.
11577 0 11	Foundation Fund	11577 0 11	
5500 0 0	Do. (Cotton Reconstruction Board Grant)	5500 0 0	
861 9 6	Do. (Diplomas Account)	861 9 6	
250 0 0	Do. (London Office Reserve Account)	250 0 0	
2500 0 0	Crompton Prize Fund	2500 0 0	
508 0 0	Life Membership Reserve Account	529 0 0	
97 10 0	Perpetual Membership Reserve Account	97 10 0	21315 0 5
269 15 0	Scholarship Scheme Reserve Account		290 9 4
26 6 8	National Certificates Scheme		27 16 6
81 3 3	Competition Scheme: Income and Expenditure Account Balance		68 10 11
	Life Membership Subscription Account— Balance as on 31st December, 1935	8 10 7	
8 10 7	Less 10% of £85 8s. 1d. transferred to Subscription Account	8 10 7	— — —
225 0 3	Subscriptions Paid in Advance		151 2 0
210 1 0	Sundry Creditors and Reserves		374 2 4
	Bank Overdraft—		
259 3 6	General Account		286 13 5
0 6 1	Foundation Fund		— — —
£22374 6 9			£22513 14 11

Cr.

1935 £ s. d.	ASSETS.	£ s. d.	£ s. d.
	Furniture, Fittings and Library Accounts—		
	Balance as on 31st December, 1935	380 12 9	
	Additions during Year	75 3 0	
		455 15 9	
380 12 9	Less Depreciation	85 2 10	
			370 12 11
	London Furniture Account—		
	Balance as on 31st December, 1935	17 12 7	
17 12 7	Less Depreciation	3 4 1	
			14 8 6
	Investments Account (See Schedule)—		
18030 15 0	Foundation Fund	18030 15 0	
2500 0 0	Crompton Prize Fund	2500 0 0	
155 0 0	Life Membership Account	155 0 0	
97 10 0	Perpetual Membership Account	97 10 0	
			20783 5 0
	Sundry Debtors—		
	Journal Account—		
440 17 3	Outstanding Adverts.	376 10 0	
26 14 6	Outstanding Reprints, etc.	23 7 6	
			399 17 6
83 11 9	Stock of *Chronological Records* (Estimated Value) ...		83 11 9
9 10 0	Gas and Electricity Deposits		9 10 0
— — —	Cash on Deposit—York County Savings Bank		60 18 4
18 8 0	Cash in Hand		15 3 4
13 5 6	Legal Expenses *re* Premises—Balance		10 8 6
	Revenue Account—		
	Balance as on 31st December, 1935	600 9 5	
600 9 5	*Add* Excess Expenditure over Income for Year ...	165 9 8	
			765 19 1
£22374 6 9			£22513 14 11

AUDITORS' REPORT TO MEMBERS.

We report to the members that we have examined the above Balance Sheet, together with the books and vouchers of the Institute, and that we have obtained all the information and explanations we have required. We further report that in our opinion the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institute's affairs according to the best of our information and the explanations given to us, and as shown by the books of the Institute.'

17th March, 1937. ARTHUR E. PIGGOTT, SON & CO.

37, York Street, Manchester. *Incorporated Accountants, Auditors.*

Journal Account for the Year ended 31st December, 1936

Dr.

1935 £ s. d.	EXPENDITURE.	£ s. d.
2287 4 3	To Printing, Reprints and Postages (Distribution)	2216 2 8
36 7 3	,, Literary Contributions and Abstracts	42 9 8
674 2 6	,, Salaries	675 10 0
132 3 4	,, Wages	145 18 4
70 14 6	,, Postages, Telegrams and Telephone	84 5 8
13 9 5	,, Stationery	29 7 9
178 18 2	,, Advertisement Commission	171 2 10
10 1 5	,, Travelling Expenses	25 10 8
104 4 2	,, Rent and Rates (Proportion)	113 8 6
24 15 6	,, Heating, Lighting and Cleaning (Proportion)	26 9 6
£3532 0 6		£3530 5 7

Cr.

1935 £ s. d.	INCOME.	£ s. d.	£ s. d.
2166 0 5	By Advertisements and *Journal* Subscriptions		2107 1 2
	,, *Journal* Subscriptions—		
172 10 0	Linen Industry Research Association	181 17 0	
21 0 0	Wool Industry Research Association	21 0 0	
			202 17 0
10 10 0	,, Annual Donation : The Clothworker's Company		10 10 0
126 9 4	,, Reprints		72 17 2
1028 14 9	,, Transfer from Membership Subscriptions		1046 7 8
6 16 0	,, Transfer from Foundation Fund Income from Investments Account		90 12 7
£3532 0 6			£3530 5 7

Dr. The Textile Institute—Revenue Account for the Year ended 31st December, 1936 Cr.

EXPENDITURE.

1935 £ s. d.		£ s. d.	£ s. d.
	To Rent and Rates—Manchester	340 5 5	
208 8 4	*Less* to *Journal* Account	113 8 6	226 16 11
	,, Salaries	1525 10 0	
650 0 0	*Less* to *Journal* Account	675 10 0	850 0 0
	,, Wages	484 8 8	
338 17 10	*Less* to *Journal* Account	145 18 4	338 10 4
	,, Heating, Lighting and Cleaning	79 8 6	
49 10 11	*Less* to *Journal* Account	26 9 6	52 19 0
69 19 3	,, Offices, Canteen and General Expenses		80 3 7
44 18 9	,, Meetings and Travelling Expenses		26 1 2
104 5 10	,, Postages, Telegrams and Telephones		105 18 7
123 7 7	,, General Printing and Stationery		127 8 9
6 19 6	,, Insurances		7 2 6
32 2 6	,, Audit Fee		32 6 0
13 13 0	,, Subscriptions to Institutions		5 5 0
59 15 5	,, Library Account		151 12 1
32 19 2	,, Diplomas Account Expenses		42 8 7
3 15 3	,, Medal Account		2 12 6
34 1 10	,, Painting and Decorating		1 11 2
43 19 0	,, Savings Association Contributions		43 10 0
73 14 4	,, Annual Conference Expenses		189 3 9
14 8 9	,, Bank Charges *less* Interest		2 19 4
	,, Section Expenses :—		
73 1 6	London (including Office and Rooms)	7 16 3	
16 16 1	Lancashire	19 11 9	
17 5 6	Yorkshire	23 16 2	
5 15 8	Scotland	8 6 6	
14 17 3	Ireland	4 12 4	
2 12 2	Midlands	4 2 6	68 5 6
37 19 6	,, Income Tax		69 6 0
2 17 0	,, Legal Expenses *re* Premises—Amount w/o		2 17 0
80 16 7	,, Depreciation on Furniture, etc.		88 6 11
2156 18 6			2515 4 8
208 15 1	,, Surplus Income over Expenditure for Year (1935)		— — —
£2365 13 7			£2515 4 8

INCOME.

1935 £ s. d.		£ s. d.	£ s. d.
	By Membership Subscriptions—		
	1116 Members at £2 2s.	2343 12 0	
	1 Member at £1 1s.	1 1 0	
	26 Members at £1 1s. (Half Year)	27 6 0	
	98 Junior Members at £1 1s.	102 18 0	
	7 Junior Members at 10s. 6d. (Half Year) ...	3 13 6	
	Life Members : 10% of balance	8 10 7	
	Subscriptions in Advance as per Balance Sheet, 31st December, 1935	225 0 3	
	Subscriptions in Arrear paid during 1936 ...	80 7 0	
	Interest on Diplomas, Life Membership and Perpetual Membership Investments	37 15 10	
	Special Subscription—The Weavers Company ...	21 0 0	
	Diploma Fees	138 10 0	
		2989 14 2	
1910 10 3	*Less* Amounts transferred to *Journal* Account ...	1046 7 8	1943 6 6
100 0 0	,, National Certificates Scheme—Administration Expenses		100 0 0
345 3 4	,, Foundation Fund Income from Investments Account		286 8 6
10 0 0	,, Crompton Fund Administration Expenses		20 0 0
£2365 13 7			£2349 15 0
— — —	,, Excess Expenditure over Income for Year		165 9 8
£2365 13 7			£2515 4 8

SUBSCRIPTIONS—	
TOTAL ARREARS at 31st December, 1936 ...	£474 14 3
ARREARS written off	85 18 3
Total Arrears Current	£388 16 0

Crompton Prize Fund Scheme: Competitions

Income and Expenditure Account for the Year ended 31st December, 1936

Dr. EXPENDITURE.

1935 £ s. d.		£ s. d.
43 5 5	To Balance brought forward	— — —
13 16 3	,, Printing and Stationery	27 18 3
43 13 2	,, Purchase of Specimens	31 4 1
20 15 0	,, Mounting of Specimens	21 5 0
— — —	,, Prize Awards and Expenses	163 14 6
6 13 1	,, Postages and Carriage	6 9 10
10 0 0	,, Administration Expenses	20 0 0
81 3 3	,, Balance carried forward	68 10 11
£219 6 2		£339 2 7

Cr. INCOME.

1935 £ s. d.		£ s. d.	£ s. d.
— — —	By Balance brought forward		81 3 3
134 19 0	,, Albums—Subscriptions		157 19 0
— — —	,, Competition Entrance Fees		15 6 0
— — —	,, Donation—R. Greg & Co.		5 0 0
35 0 0	,, Dividend on £1000 3½% War Stock	£35 0 0	
39 4 8	,, Dividend on £1125 4% L.M.S. Railway Stock	34 11 10	
			69 11 10
10 2 6	,, Income Tax Repayment		10 2 6
£219 6 2			£339 2 7

Foundation Fund

Income from Investments Account for the Year ended 31st December, 1936

Dr. EXPENDITURE.

1936			£ s. d.	£ s. d.
May	27	To Mather Lecture		25 0 0
Dec.	31	,, Interest on £844 9s. 2d. 3½% War Loan (Diplomas) transferred	29 11 0	
,,	31	,, Interest on £102 5s. 3½% War Loan (Life Members), transferred	3 11 9	
,,	31	,, Interest on £99 1s. 6d. 3½% War Loan (Perpetual Membership), transferred	3 9 3	
,,	31	,, Interest on £1000 3½% War Loan (Crompton), transferred	35 0 0	
,,	31	,, Interest on £4870 3½% War Loan (Scholarship), transferred	170 9 0	
,,	31	,, Interest on £569 15s. 3% Local Loans (Scholarship), transferred	13 2 10	
,,	31	,, Interest on £47 19s. 6d. 2½% Conversion Stock (Life Members), transferred	1 3 10	
				256 7 8
,,	31	,, *Journal* Account		90 12 7
,,	31	,, Revenue Account		286 8 6
				£658 8 9

Cr. INCOME.

1936			£ s. d.
Jan.	2	By Dividend £1015 1s. 3% Leeds Corpn. Redeem. Stock, *less* Tax	5 16 3
,,	6	,, ,, £569 15s. 3% Local Loans, *less* Tax	3 6 3
Feb.	3	,, ,, £1242 10s. 4% Consolidated Stock, *less* Tax	19 5 3
April	1	,, ,, £47 19s. 6d. 2½% Conversion Stock, *less* Tax	0 11 11
,,	6	,, ,, £569 15s. 3% Local Loans, *less* Tax	3 6 3
May	1	,, ,, £1000 4% Funding Loan, 1960-90, *less* Tax	15 10 0
June	1	,, ,, £15939 18s. 10d. 3½% War Loan	278 18 11
July	1	,, ,, £1015 1s. 3% Leeds Corpn. Redeem. Stock, *less* Tax	11 8 9
,,	7	,, ,, £569 15s. 3% Local Loans, *less* Tax	3 5 2
Aug.	10	,, ,, £1242 10s. 4% Consolidated Stock, *less* Tax	18 19 0
Oct.	1	,, ,, £47 19s. 6d. 2½% Conversion Stock, *less* Tax	0 11 11
,,	5	,, ,, £569 15s. 3% Local Loans, *less* Tax	3 5 2
Nov.	1	,, ,, £1000 4% Funding Loan, 1960-90, *less* Tax	15 5 0
Dec.	1	,, ,, £15939 18s. 10d. 3½% War Loan	278 18 11
			£658 8 9

Scholarship Scheme

EXPENDITURE.

1936			£ s. d.
Dec.	31	To Scholarship Holders Maintenance Allowance and Fees—Joseph Airey	145 0 0
,,	31	,, Travelling Expenses	17 17 6
,,	31	,, Balance carried forward	290 9 4
			£453 6 10

INCOME.

			£ s. d.
1935 Dec.	31	By Balance brought forward	269 15 0
1936 Dec.	31	,, Interest on £4870 3½% War Loan	170 9 0
,,	31	,, Interest on £569 15s. 3% Local Loans	13 2 10
			£453 6 10

SCHEDULE OF INVESTMENTS

(at Cost or Value at original date of gift) **as on 31st December, 1936.**

			£	s.	d.	£	s.	d.
Foundation Fund—								
£3737 14 9	3½% War Stock	... ...	3503	7	0			
£4789 9 5	Do.	... ...	4789	9	5			
£ 48 16 3	Do.	... ...	49	14	1			
£ 105 5 3	Do.	... ...	106	14	0			
£ 102 17 6	Do.	... ...						
£4870 0 0	Do.	(Scholarship Scheme)	5355	0	0			
£240 0 0	Do.	(London Section)						
£650 0 0	Do.	(Diplomas)	661	9	6			
£194 9 2	Do.	(Diplomas...)	200	0	0			
£1000 0 0	4% Funding Loan 1960-90	... ...	800	0	0			
£1242 10 0	4% Consolidated Stock	... ...	1050	0	0			
£569 15 0	3% Local Loans (Scholarship Scheme)	...	500	0	0			
Beanland Bequest—								
£1000 0 0	3% Leeds Corporation Redeemable Stock		1015	1	0			
						18030	15	0
Crompton Prize Fund—								
£1000 0 0	3½% War Stock	... ...	1000	0	0			
£1125 0 0	4% L.M.S. Rly. Preference Stock	...	1500	0	0			
						2500	0	0
Life Membership Account—								
£52 5 0	3½% War Stock	... ...	53	14	6			
£50 0 0	Do.	... ...	51	5	6			
£47 19 6	2½% Conversion Loan	... ...	50	0	0			
						155	0	0
Perpetual Membership Account—								
£99 1 6	3½% War Stock	... ...				97	10	0
Nominal Value—								
£20925 3 4								
						£20783	5	0

The market value of the above securities on
31st December, 1936, was approximately £21971 17 9
(Securities at National Provincial Bank Ltd.).

Audited and found correct,
9th February, 1937.
37 York Street, Manchester.

ARTHUR E. PIGGOTT, SON & CO.,
Incorporated Accountants, Auditors.

Yorkshire Section

At a meeting of the Yorkshire Section of the Textile Institute, at Bradford, on the 12th November, 1936, under the Chairmanship of Mr. G. Haigh, F.T.I., the following lecture on "Olive Oil and other Combing Oils" was delivered by Mr. Walter Garner, M.Sc., A.T.I.

The requirements of a combing oil may be summarised as follows :—

1. Freedom from oxidation.
2. Ease of scouring even after long storage.
3. No tendency to smell or become rancid.
4. Suitable viscosity.
5. Pale colour.
6. Satisfactory as regards insurance companies' requirements.
7. Steady price.
8. Regular quality.
9. Abundant sources of supply.

Olive Oil has in the past been widely used for wool oiling, despite the fact that it does not entirely satisfy even one of these conditions.[4, 6] Even the best olive oil is liable to oxidise, tends to become difficult to scour after storage, and may develop rancidity and smell. Its viscosity, initially rather on the high side, by oxidation tends to become greater, giving rise to stickiness. Its colour could be paler with advantage. Many qualities give so bad a Mackey test that they are turned down by the analysts, acting on behalf of insurance companies. The price fluctuates within very wide limits and often unexpectedly. The quality and quantity vary from season to season, and from one producing country to another. The sources of supply are limited and a poor crop in any one district immediately causes a shortage.[1]

The estimated average annual production of olive oil for the main producing countries for the years 1930–34, expressed as percentages of the total world production, is given in the following table :—

Spain	38·43.	per cent.
Italy	25·24.	,,
Greece	14·07.	,,
North Africa	9·51.	,,
Levant	4·82.	,,
Portugal	5·89.	,,
France, &c.	2·06.	,,

The total world production varies between 600,000 and 900,000 tons per annum, and the requirements of producing countries (mainly as food) are estimated at about 650,000 tons. The English textile trade as a whole, uses perhaps 7,000 tons per annum. It is evident therefore, that woolcombers will probably always be able to obtain supplies, but it is also evident that the price will depend upon the margin between the production of olive oil and the requirements of producer countries. The normal margin is so small that adverse conditions of any kind tend to cause the price to textile consumers to rise disproportionately.

These remarks are true even of the products of growers situated in the same district. The description Malaga olive oil for example denotes that the olive oil has been exported from Malaga, and the efficiency and equipment of the several olive plantations in the country feeding the port of Malaga vary considerably.

The differences between one olive oil and another arise from many causes. Differences in soil, in weather conditions, in the particular species of olive tree grown, in the time elapsing between the gathering of the olives and the pressing,

in the oil extraction system used, in the efficiency of filtration, and so on, all cause differences in quality, and to some extent in the composition of the oil.

These economic questions are in themselves sufficiently serious, but the criticisms of olive oil based upon its chemical composition are of equal importance.

The technical quality of olive oil used for wool oiling has probably the following average composition :

76	per cent	olein
10	,,	palmitin.
10	,,	linolin.
3	,,	oleic acid.
1	,,	linolenin.

Lower grade oils may contain a proportion of oxidised fatty acids, lactones, and possibly some " linoxyn ".

It is clear from this analysis that on purely chemical grounds olive oil will show a pronounced tendency to oxidisation. This tendency is assisted in every possible way by the woolcomber, who spreads the oil in the thinnest possible layer over the surface of the wool ; only $\frac{1}{4}$ oz. of oil is used to lubricate the estimated 70 square yards surface area of 1 lb. of wool.

When olive oil is exposed to the action of light and air in thin films, three main changes may be expected :

1. Hydrolysis.
2. Oxidation.
3. Polymerisation.

Hydrolysis

Naturally occurring enzymes are invariably present and act by splitting the glycerides up into free fatty acid and glycerine. When olives are plucked by hand and pressed immediately, an oil is obtained containing very little free fatty acid and only traces of enzymes from the fruit pulp. When however the ripe olives are knocked down by means of sticks, and allowed to lie in heaps on the ground for some time before pressing, the enzymes have time to act and the pressed oil contains high percentages of free fatty acid, sometimes as much as 20 per cent. The refusal to buy olive oil with more than 5 per cent. free fatty acid, which is common in the Bradford trade, is therefore well founded because high acidity indicates as a rule, careless and inefficient handling. Freshly pressed oils which have not been long in contact with the pulp will as a rule be the least liable to rancidity. It should however be clearly realised that it is not the high percentage of fatty acid which causes rancidity ; it is the enzymes which are present in carelessly handled oils.

Oxidation

Of the three glycerides present, the palmitin will probably be practically unaffected by exposure to air. The olein molecules will suffer slow oxidation and the linolin molecules will be attacked much more rapidly.

The course taken by the oxidation depends upon many factors, but in general the oleic acid grouping may tend to be converted to a hydroxy stearic acid group, or will form peroxides which split into bodies of the type of nonylic and azelaic acids and aldehydes. If oxidation were to stop here it is clear that subsequent scouring would be improved rather than otherwise. In practice, however, other reactions often occur which result in the production of resinous bodies difficult to emulsify and therefore resistant to scouring. It is very probable that these resins are produced by polymerisation of the aldehydes resulting from primary oxidation and by condensation of aldehydes with hydroxy acids, and with unsaturated groupings.

Linoleic acid oxidises much more rapidly than oleic and though some innocuous hydroxy acids are produced the usual reaction results in resinous bodies which on more prolonged exposure are converted to inert, neutral bodies insoluble in petroleum ether. Another possibility is that any free fatty acid which becomes oxidised into an oxy acid may form a lactone.

Polymerisation.

The presence of a $>C=C<$ group seems to confer upon any glyceride or ester of a long chain fatty acid the power of polymerisation. This power is more marked as the number of $>C=C<$ groups increases. Polymerisation is however, probably due less to interaction and condensation at the double bonds than to the activity of aldehyde groups produced by oxidation.

Polymerised oils have a higher specific gravity because of the closer spatial arrangement. The increased size of molecule and the partial linkages between molecules cause increased viscosity. Polymerisation often reduces the ease of scouring because the number of polar groups accessible to the detergent solution is greatly decreased, whilst large molecules, high internal cohesion, and high viscosity do not favour easy removal.

The lactones, aldehydic condensation products, and resinous polymerised bodies are all much more difficult to scour out than olive oil or normal glycerides. It is the liability to their formation which determines the suitability of an olive oil for wool oiling, and the fact that even the best olive oils contain serious amounts of bodies of the more easily oxidised classes must be regarded as a great disadvantage.

Consideration of the above indicates very definitely that olive oil is not from the chemical point of view the ideal combing oil; it has been employed almost exclusively in the past because nothing better has been available. Previously, when considering possible alternatives to olive oil, attention has chiefly been paid to other vegetable oils and to mineral oils. Some of the commercially available oils are set out in the following table, arranged in order of their iodine values, and grouped into three commonly accepted classes of drying oils, semi-drying oils, and non-drying oils.

	Iodine Value.
Drying Oils	
Linseed	173–201.
Soya	137–143.
Whale	121–146·6.
Semi-Drying Oils	
Maize	111–130.
Cottonseed	108–110.
Sesame	103–108.
Rape	94–102.
Non-Drying Oils	
Almond	93–97.
Arachis	83–100.
Sperm	81–90.
Teaseed	88.
Castor	83–90.
Olive	79–88.
Lard	76–85.
Neatsfoot	69–76.
Palm oil	51–57.
Tallow	35–46.
Palm kernel	13–17.
Mineral oil	14.
Mineral oil lightly refined ...	3.

The drying and semi-drying oils are totally unsuitable. Of the non-drying group, some, such as neatsfoot and almond, are ruled out by price and amount available, whilst others such as cottonseed are solid fats. This leaves only the following for serious consideration: arachis, sperm, teaseed, castor, and mineral oils, to which may be added commercial oleic acid.

The table below gives more detailed analytical data for these oils.

Oil	Iodine Value	Saponification Value	Specific gravity	Viscosity (Redwood) Secs. 70°F.
Arachis	90	190–196	0·916–0·920	307–429
Sperm	88	123–147	0·876–0·883	137
Teaseed	87	195	0·916–0·920	321
Castor	86	183–186	0·950–0·960	2500
Olive	84	185–196	0·916–0·920	400
Mineral	18	—	0·89	2900
Refined Mineral ...	2	—	0·87	290

Practical experience with olive oil has shown that it is very near the border line for safety so far as oxidation is concerned, and the oils above it in this table must therefore be open to suspicion.

Arachis Oil was fairly extensively used during the war period and it is known from this practical experience that provided the oiled wool be processed and scoured within a few weeks, ordinary arachis is a fairly safe oil. It is also known that even under these conditions for no apparent reason, oxidation faults often developed, whilst oiled tops stored for twelve months or so invariably suffered serious oxidation. This question may be left open for the moment with the remark that even on a definite basis of early scouring the use of ordinary arachis oil is somewhat risky.

Three oils of about the same iodine value are next in the list, namely olive, teaseed, and sperm. Teaseed oil is chemically indistinguishable from olive oil and there seems no reason at all why it should not be as suitable as olive. Works experience however has proved very conclusively that the use of teaseed is attended with serious risk. There is also another factor to be considered, that is, the commercial regularity of the product. If teaseed be bought in November–December, i.e., when the crops have been freshly gathered, the acidity is low, (2 per cent.–7 per cent.), but supplies at later dates contain fatty acid amounting to 20 per cent–25 per cent. This is due to the poor organisation and inefficient operation of the plantations, which permits the fruit to lie about in heaps for long periods before pressing. This inefficiency extends to carelessness about cleanliness, filtration, etc., and makes teaseed an unsatisfactory and unreliable oil at present. It must also be remembered that the total world production is not very large.

Sperm Oil is, strictly speaking, not an oil at all, but a liquid wax. The vegetable oils are glycerides of fatty acids whilst sperm oil is a complex mixture of compounds of the higher fatty alcohols with fatty acids, and contains very little glycerine. It is a fish oil and like all fish oils contains, in addition to the usual type of oxidisable bodies present in vegetable oils, certain substances even more easily oxidised.

The oxidisability of a pure fatty body is very well indicated by the amount of bromine with which it will combine ; the greater the amount of bromine the greater the ease of oxidisation. Olive oil yields mainly the di- and some tetra-bromide. Arachis oil yields in addition detectable amounts of hexa-bromide, whilst sperm oil yields a small percentage of octo-bromide. The bodies forming hexa-bromides are highly dangerous in a wool oil; they are the substances conferring upon linseed oil its power to oxidise to solid resins. The bodies forming octo-bromides are still more dangerous owing to the extreme ease with which they oxidise to form resins.

It is evident that sperm oil is to be classed as dangerous from the point of view of oxidation. It has also the further disadvantages that its viscosity is very low, much lower than olive, that it has the characteristic fishy smell of marine oils, and that it becomes solid in cold weather much sooner than olive.

Castor Oil next requires consideration. Tested for oxidation in the Mackey apparatus, it is no better than olive oil. Although it does not "dry" to a solid film like the unsaturated bodies in arachis, it nevertheless is much thickened by air oxidation and tends to become gummy and sticky. These qualities do not commend it for textile use.

Its viscosity is very high, too high for use alone. It is therefore necessary to thin it down with some very thin oil and the only cheap products available are mineral oils, sperm oil, and oleic acid. The maximum amount of mineral oil allowable by insurance companies (30 per cent.) is insufficient to make it thin enough, and hence the thinning must be continued by oleic acid, which gives an oil of high free fatty acid content, or with sperm oil, which is objectionable. Examination of the scouring properties of these mixtures showed that they were more difficult to scour out than olive oil unless strongly alkaline baths were used, coupled with mechanical squeezing.

Mineral Oils

Crude mineral oil is a very complex mixture of substances, some of which are extremely stable to oxidation, others being extremely unstable. Refining is designed to remove the unstable bodies, but of course reduces the yield of oil in addition to being an expensive process. For commercial lubricating oils a compromise is arrived at by removing the majority of the unstable bodies.

The iodine value of a lubricating oil lies between 10 and 20 and it might be expected therefore that such an oil would be much less easily oxidised than olive oil (I.V. 84). The bulk of the lubricating oil consists in fact of the very stable paraffins (I.V. = 0), but the iodine value, which is an average of that of the constituents is due to the presence of small amounts of very easily oxidised bodies of high iodine value. These substances oxidise to yellowish brown resins which, once formed, are almost impossible to remove by scouring.

For textile purposes, only an exceptionally well refined mineral oil of water white colour and approaching medicinal paraffin in purity, can be considered with safety. Given such an oil, which so far as lubrication during combing and spinning is concerned, is entirely suitable, the question of scouring must be considered. It is well known that mineral oils are very difficult to scour out and although Speakman and others have attempted to overcome this disability with a considerable measure of success, it cannot be said that even the treated oils are proof against scouring trouble.

Insurance

A further factor is the attitude of the fire insurance companies, which charge increased premiums when oils other than certain specified "safe" oils (such as olive) are used. Mineral oil is placed in the class carrying the maximum surcharge.

So far as spontaneous combustion is concerned, there is no doubt that mineral oil is safer than olive oil. Fires due to this cause in worsted mills are however extremely rare. Statistics prove very clearly that almost all fires in the worsted industry are due to accident or carelessness. This being so, the important properties of an oil, considered from the point of view of fire risks, are (a) the ease of ignition, and (b) the ease of burning. Mineral oils suitable for woolcombing have much lower flash points than olive oil, indicating easier ignition; moreover, once ignited they burn much more fiercely. Taking such points into consideration, there seems little doubt that the attitude of the insurance companies is correct; indeed it may be argued with reason that the present restrictions upon the use of mineral oil should be increased rather than decreased, so far as worsted mills are concerned.

It seemed obvious from the foregoing that work on the lines indicated was unlikely to lead to a successful conclusion. It was considered that either some natural oil must be modified, or an entirely new product must be discovered.

Modification of Natural Oils

In view of the insurance position, mineral oils may for the time being be left out of consideration. The question was asked—why does olive oil, normally a safe oil, occasionally oxidise badly on tops without any apparent reason? It seemed likely that the answer would be found in the properties of some constituent of the oil. Palmitin was above suspicion, leaving the glycerides of oleic and linolic acid. It is well established that the linolic acid glycerides oxidise more easily than those of oleic acid and there is an evident possibility that controlled oxidation of olive oil may enable the linolic glyceride to be oxidised to harmless substances, whilst leaving the main bulk of the oil, the oleic glycerides, unaffected.

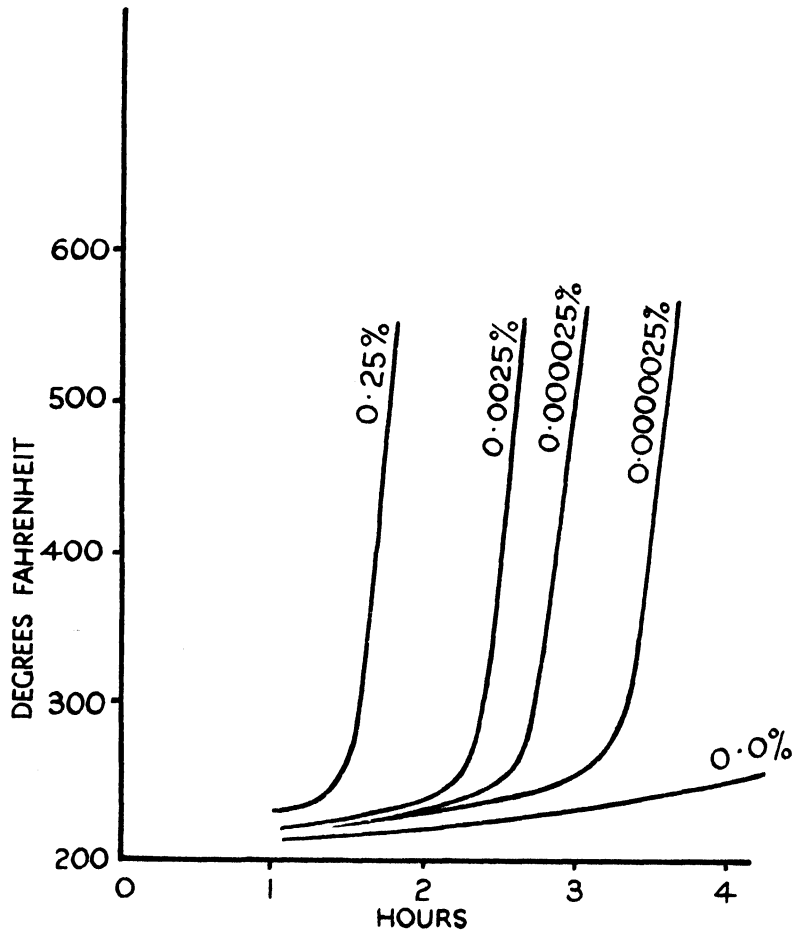


Fig. 1. Mackey Tests.
Effect of additions of ferric oleate to Malaga olive oil.

It was in fact found possible to oxidise the linolic glyceride preferentially by "blowing" olive oil at a temperature of 150°C. for some hours. The preferentially oxidised oil was expected to show an improved Mackey test, but it was found that whilst with some olive oils an improvement was obtained,

with others, the Mackey test was unexpectedly much worse after "blowing" than before.

These curious results were finally found to be due to the action of minute traces of impurities in the oils, which acted as oxidising catalysts, causing the oxidation to be very greatly accelerated. Two types of catalyst were discovered: (1) Active Catalyst. This type is present in all commercial non-drying oils in an active form. It can be removed by careful filtration, and it is destroyed by heat. (2) Potential Catalyst. This type is also usually present in commercial oils; it is normally without influence upon the rate of oxidation of the oil, but it is stimulated into activity by heating or storage. It cannot be removed by normal

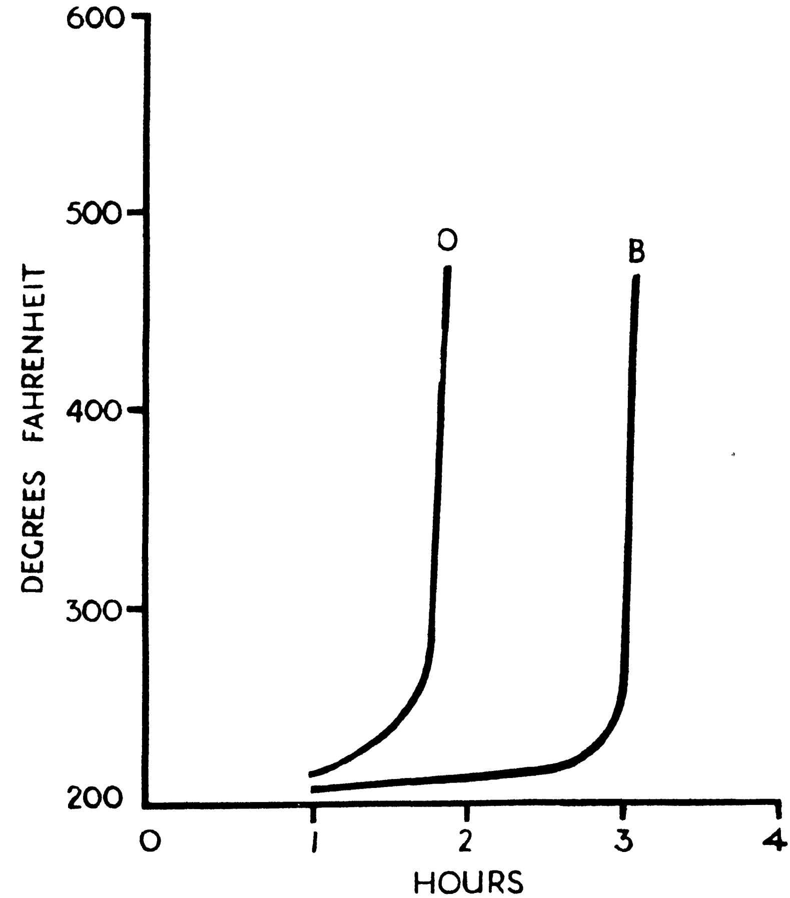


Fig. 2. Mackey Tests.
O.—Olive Oil. B.—Olive oil with 0.5 per cent. β-naphthol.

filtration. The catalysts were found to be mainly compounds of iron, cobalt and manganese. The influence of such bodies upon the drying of oils has of course been known for a long time in the paint industry, but it was interesting to find that they were present in natural oils in sufficient amount to affect the oxidation.

Fig. 1 shows the influence upon the Mackey test of additions of various amounts of ferric oleate to an olive oil. Even one part per million has a most pronounced effect, and it must be remembered that this proportion indicates only one molecule of ferric oleate to one million molecules of oleic acid glyceride.

When iron and other metallic catalysts are carefully removed from an olive oil, the oil does not exhibit a temperature rise in the Mackey test. This indicates that the linolic acid content is not the primary cause of a bad Mackey test. To confirm this, a cottonseed oil which had a very bad Mackey test was freed from metallic catalysts, and the treated oil was found to have a much better Mackey test than most olive oils, despite its much higher content of linolin. The Mackey test, then, does not indicate the degree of unsaturation of an oil, as has frequently been stated. It indicates mainly the effective activity of the catalysts present. Nevertheless, it would seem that a given amount of catalyst (e.g., 0·01 per cent. ferric oleate) has an effect, which increases with the degree of unsaturation of the oil.

Just as traces of certain metallic salts promote oxidation, so traces of bodies classed vaguely as antioxidants repress oxidation. Thus, E.P. 181365/22 recommends phenols for this purpose, and the effect of β-naphthol upon the Mackey test is indicated in Fig. 2.

From these curves it would be expected that the oil containing β-naphthol had not oxidised. Experimental work, however, quickly disproved this. The fact that an oil does not give rise to the development of a high temperature in the Mackey test does *not* mean that the oil remains unoxidised as the following table clearly illustrates. Moreover, a pure medicinal paraffin in the Mackey apparatus does not often rise above 205° F. and hence, when an oil reaches the jacket temperature, some exothermic oxidation must be taking place.

Test.	Oil removed from Mackey Apparatus.	
	at 360° F. after 2 hrs. (no antioxidant)	at 232° F. after 5 hrs. (antioxidant)
Iodine Value	58·0	54·2
Free Fatty Acid	11·8	8·3
Specific Gravity	0·9598	0·9664
Acetyl Value	75·4	74·8
Saponification Value	226·5	232·5
Colour	deep yellow	pale yellow
Acetyl Saponfication Value	261	276

An antioxidant of the type of β-naphthol will be effective only until it is consumed, and β-naphthol in fact merely delays the onset of the exothermic oxidation in the Mackey test, but does not prevent it.

It is supposed that in an oily body such as ethyl oleate, combination with molecular oxygen does not take place at normal temperatures. At higher temperatures the molecules are able to combine directly with molecular oxygen with the probable formation, in the first place, of a peroxide.

$$R-CH=CH-R+O_2 \rightarrow R-\underset{\displaystyle O\,-}{\underset{|}{CH}}-\underset{\displaystyle O}{\underset{|}{CH}}-R$$

Any external influence which causes an increase in the number of active molecules will increase the oxidation. Thus exposure to light of an oil containing catalyst increases the amount of peroxide present and also makes the oil have a poorer Mackey test, because the light energy is transferred *via* the catalyst to the oil molecules. Similarly, when an oil is heated the mean energy of the molecules increases, the number of active molecules increases, and the rate of oxidation also speeds up. Above a certain critical temperature the majority of the oil molecules will be in the active state and the oil will oxidise rapidly. Thus pure ethyl oleate does not oxidise exothermically with the Mackey apparatus at 212° F., but gives rise to a violent exothermic reaction when the

jacket is at 245° F. This suggests that 212° F. is below the critical temperature and 245° F. is above it.

It has already been mentioned that oxidation may take one of two courses in the Mackey test one of which is exothermic, The similarity in the analytical figures given by oils after heating in the Mackey apparatus suggests that the exothermic action results from the further oxidation of the end products of a primary reaction. Aldehydes produced by the decomposition of the peroxides may be the end products in question.

$$\begin{array}{c} O - O \\ | \quad\;\; | \\ R-CH-CH-R \end{array} \rightarrow R-CHO+R-CHO$$

They may oxidise exothermically *via* a chain reaction to give acids or they may polymerise to form resinous bodies.

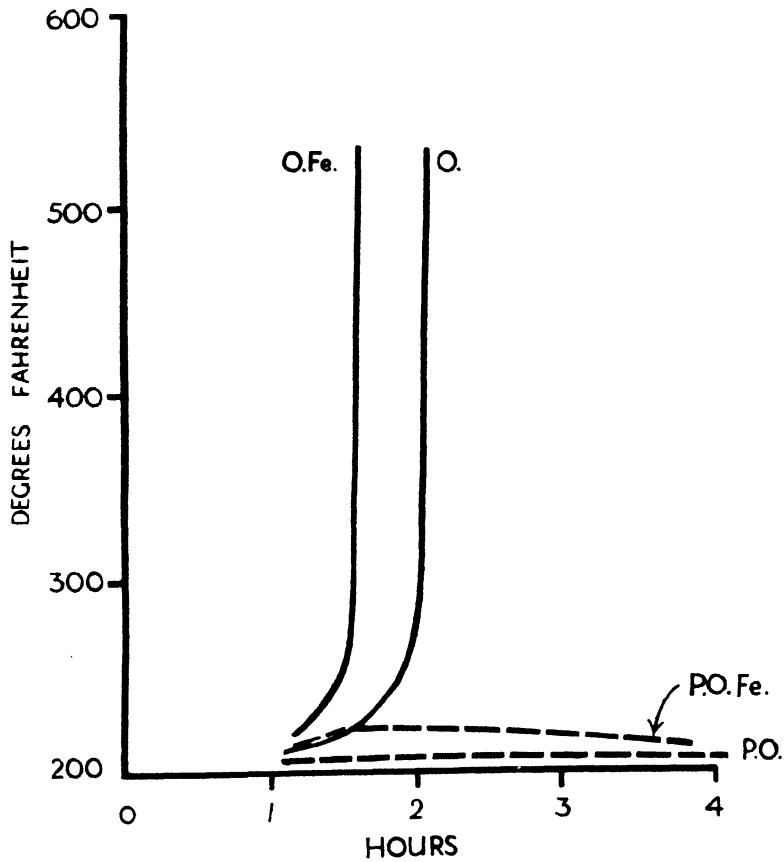


Fig. 3. Mackey Tests.
O.—Olive oil. O.Fe.—Olive oil with 0.01 per cent. ferric oleate.
P.O.—Nilox processed olive oil P.O.Fe.—Nilox processed olive oil with 0.01 per cent. ferric oleate.

In order to minimise for commercial purposes the oxidation of olive oil, it is therefore necessary first to devise a simple and inexpensive method of removing oxidising catalysts, and subsequently to find some means of ensuring that the activity of iron salts picked up by the processed oil will be nullified.

Fig. 3 illustrates the success which has been attained with olive oil treated according to the Nilox Process. The original olive oil has a bad Mackey test,

which is made even worse by the addition of 0·01 per cent. ferric oleate. After processing oil has an almost perfect Mackey test which is scarcely affected by the addition of 0·01 per cent ferric oleate. This patented process can be applied to most vegetable oils and in particular has been used with arachis oil. Fig. 4 gives the results of treating a crude arachis oil. It is clear that the processed arachis oil is as stable to oxidation in the Mackey test as processed olive oil, and more stable than the majority of commercial olive oils.

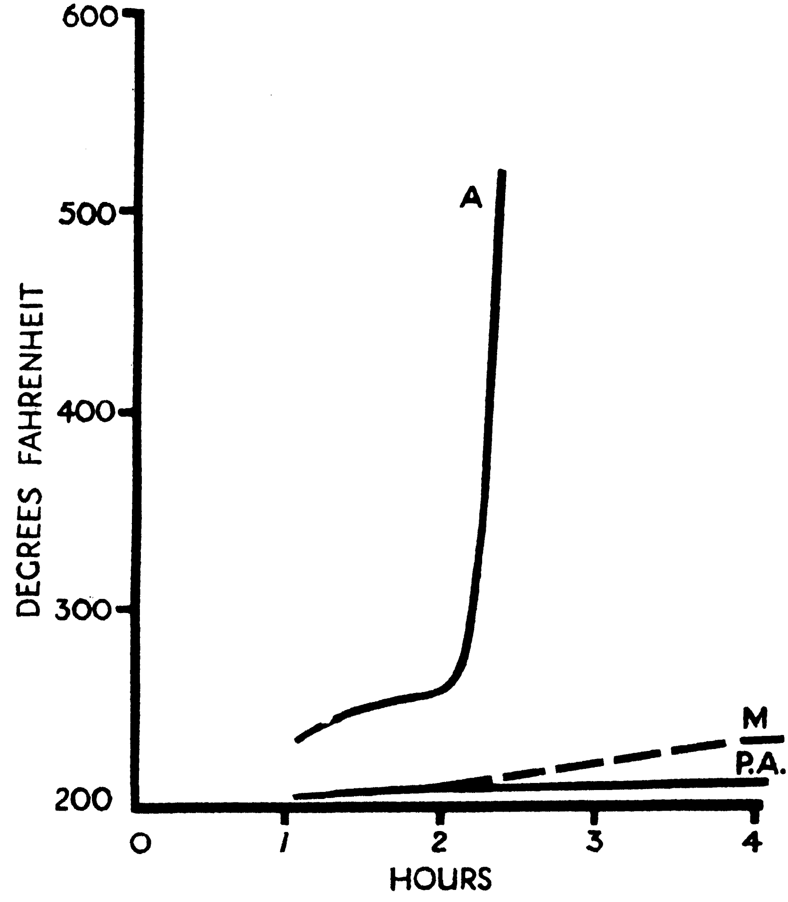


Fig. 4. Mackey Tests.
A.—Arachis oil. M.—Malaga olive oil. P.A.—Nilox processed arachis oil.

The following are typical analytical data for the processed oils, in comparison with normal olive oil.

	Olive	Processed Olive Oil	Processed Arachis Oil	Ester Oil S
Free Fatty Acid	4%	4%	4%	4%
Unsaponifiables	1%	1%	1%	0%
Mackey Test	ignites after 2 hrs.	214° F. at 5 hrs.	217°F. at 5 hrs.	214°F. after 8 hrs.
Viscosity	400 secs.	410 sec.	350 secs.	320 secs.
Flash Point	600°F.	600°F.	580°F.	400°F.
Cold Test	–6°C.	–6°C.	4°C.	–8°C.
Iodine Value	85	81	88	40

Although the processed oils represent a considerable advance upon ordinary olive oil, they yet fall short of the ideal combing oil. Both the olive oil and the arachis oil contain from 10 per cent.–20 per cent. of linolic glycerides, and no oil containing such amounts of very easily oxidisable bodies can be considered ideal.

Attempts were therefore made to synthesise an oil from raw materials which were free from such easily oxidised bodies. For a long time these efforts met with no success because the requirements were very severe. The synthetic oil must be liquid at ordinary temperatures, have a good cold test, a safe flash point, no appreciable smell, a pale colour, a low iodine value, good scouring

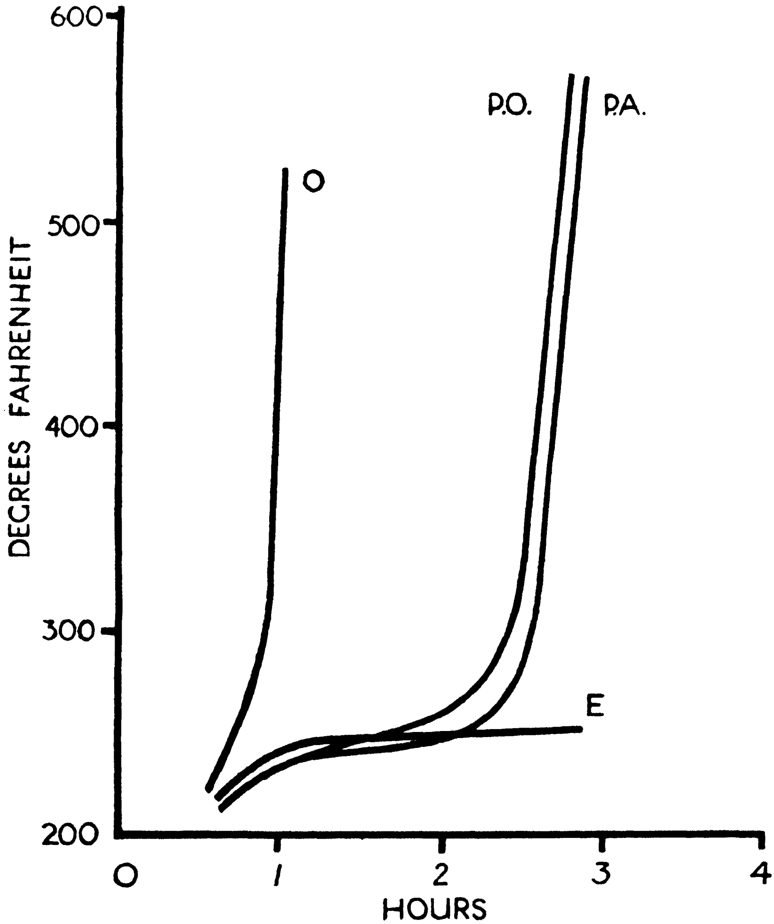


Fig. 5. Mackey Tests. Jacket at 245° F.
O.—Ordinary olive oil. P.O.—Nilox processed olive oil.
P.A.—Nilox processed arachis oil. E.—Nilox Ester Oil S.

and emulsifying properties, little tendency to oxidation and rancidity, insensitivity to iron salts, and a good Mackey test. It must, moreover, be made from cheap raw materials which are available in quantity. Eventually an ester was found which satisfied all the above conditions. The analytical data for this ester are in the table above.

The indications given by the low iodine value and the excellent Mackey test that the ester oil will not oxidise when used as a combing oil, have been fully

borne out by practical experience. The extraordinary stability to oxidation is illustrated in Fig. 5. The jacket of a Mackey apparatus was filled with glycerine instead of water, and a stirrer was fitted. The test was carried out exactly as usual except that the jacket was maintained at 245° F. instead of 212° F. Under these very severe conditions, even the processed olive and arachis oils oxidised fairly rapidly, though much less rapidly than the unprocessed oils. The ester oil, however, gave an excellent test, the results indicating the absence of any tendency to exothermic oxidation. The influence of iron on this synthetic oil in the ordinary Mackey test is illustrated in Fig. 6.

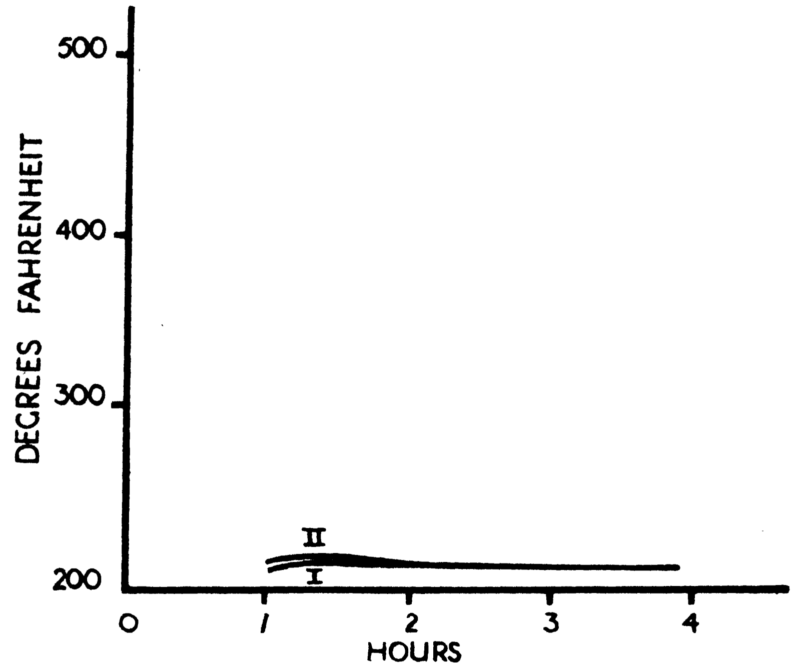


Fig. 6. Mackey Tests.
I.—Nilox Ester Oil S. II.—Nilox Ester Oil S with 0.1 per cent. ferric oleate.

Parallel to the above experiments, the oils were exposed on botany sliver to an accelerated ageing test. The slivers contained 3 per cent. of oil as usual. The test consisted in hanging the oiled wool in a stove at 85° C for several days, in a moist atmosphere. Pulls of the sliver were taken at intervals, the oil extracted and analytical figures determined. The Nilox processed oils, whether olive or arachis, oxidise much less slowly than the unprocessed oils, whilst the ester oil also does not oxidise rapidly.

REFERENCES

[1]*Öle, Fette*, Nov.1936.
[2]Mackey & Ingle, *J.S.C.I.*, 1916, p. 455.
[3]Garner & Leach, *Analyst*, May 1935.
[4]*Wool Record*, 1936, Oct. 1st.
[5]*Wool Record*, 1936, Oct. 8th.
[6]Garner, *Analyst*, Aug. 1936.
[7]Garner, *J.S.D.C.* (in press).
[8]Garner & Elwsorth, *Analyst* (in press).

Reviews

Applied Chemistry for Engineers. By A. F. H. Ward. Published by Longman, Green & Co. (Pages xi and 127. Price 5/-.)

Since every industry is more or less mechanised, the employment of an engineer is universal even in the smallest works and it has come to be usual for him to be concerned in all sorts of matters outside the care of machinery, for example, water, fuel, corrosion, insulation, to mention only a few. In short, the more chemistry an engineer knows, the better fitted he will be for his responsibilities. This fact is recognised by the introduction of some chemistry into courses of training for engineers. Some day when a degree course in " Chemical Engineering " is more general, it is probable that very many factory engineers will have been so trained : in the meantime it is interesting to note that Manchester is a pioneer in starting such a course. Men trained in Chemical Engineering should be of particular value to the Textile Industry.

The teaching of a subject is usually facilitated by the assistance of suitable text-books. The one before us by Mr. Ward, who is on the staff of the Manchester College of Technology, is intended to help students of the several branches of Engineering to gain chemical information on subjects which will specifically come under their notice in their practical life. Water is such a variable commodity that it can do great harm in a boiler or a textile process if it has the wrong composition. This little book tells how to take samples and to perform the various tests which disclose its composition and goes into such matters as softening, scale formation, priming, etc., which form part of the daily worries of the boiler engineer.

The next section has reference to corrosion, the problems of which are complex because there are so many variable factors. An effort is made in limited space to indicate the essentials of this subject. Nowadays protection against corrosion is often gained by means of protective films. A final section deals with the tests to be applied to coal and oils.

Considered as a whole the book is very good. It is full of practical information, handy for reference, which it would be better to have in general form, if not in exact detail, firmly in one's memory. The book will help materially towards this desirable end. The march of technical progress involves a greater degree of technical knowledge by all of us ; such books help us to possess it. E.F.A.

Department of Scientific and Industrial Research. Report for the Year 1935-36. London. H.M. Stationery Office, 1937. 3/– net.

The issue by the Advisory Council of the Department of Scientific and Industrial Research of the Annual Report of the Department, has now become an event of major importance in the world of applied science. Gone indeed are the days in which such an indictment as the late Professor Perry's " Britain's Neglect of Science " could appear. The Department concerns itself with every branch of science, keeping the closest possible contact with all sections of industry. It deals with the nation's food, health, clothing, lighting, heating and even, by virtue of researches in radio transmission, with its amusement and education.

The attention of those engaged in industries in which the skilled craftsman has always been and is likely to remain of fundamental importance, is called to the following paragraph quoted from the Report of the Advisory Council :—

" The historian of the future will probably point to the last five years as a period marking an important development in the industrial outlook of this country. These years have witnessed the fruition of the policy adopted by several large industrial undertakings of setting well balanced teams of research workers, including chemists, physicists, engineers and, where necessary, biologists, to solve a particular problem or to develop a new product. This method of attack has led to the steady improvement of the efficiency of electric lamps, to the position this country has won in high-definition television, to the development on a commercial scale of the huge plant for the conversion of coal into oil by hydrogenation, to the growth of the plastics industry and to many other important advances.

This country has never been lacking in men of genius whose inventive capacity can give birth to the ideas which bring about industrial advances. What is new, in this country, in present times is the way in which industry has taken up these new ideas and brought them to the stage of industrial application by team work in which the scientists, the technical men and in fact all the departments into which a great business is organised, have worked side by side in the practical attainment of an objective. Partly for economic reasons, partly because of the high degree of specialisation which the advance of knowledge has made inevitable in scientific fields, the future no longer lies with industries that are content to make sporadic advances at the call of the brilliant individualist. Co-operation, team work, and an extensive organisation on the technical side are essential for success. Co-operation can never win its fullest success until the contacts between men of ideas in industry and men of ideas in science are as closely knit as possible."

Everyone engaged in the application of science will heartily endorse this. Some will undoubtedly go further and point out that efficiency in team work is not really difficult to obtain when all the members of the team have the same common outlook which is conferred by scientific training. Their trivial differences, like debates in Parliament, are to be encouraged as they result in discussion which ensures the consideration of their problems from every point of view. Of at least equal importance and far greater difficulty of attainment is the desirable co-operation between the scientists and the skilled "practical men." The latter have knowledge that cannot be acquired except by actual industrial experience. For various reasons they tend to distrust those who have had a scientific training. The efficient welding of the knowledge of the scientist to that of the craftsman will prove a far greater problem than the assembling of "well-balanced teams of research workers," the removal of well-established prejudices being very difficult.

The application of science to industry is gradually wearing down the opposition which it has encountered for so long. It used to be difficult to provide incontestable evidence in terms of cash of benefits to industry resulting from its co-operation with science. It would be really interesting to know the reactions of the sceptics to such cases as that of the saving effected in the dairying industries. The polluting character of the effluents from dairies and milk product factories were reduced by 99 per cent. with one plant and by 97 per cent. with another plant so that fish could live in the undiluted final effluent. Such a gain is difficult to evaluate in terms of money. Suggestions were made for reducing the losses of milk, cream, etc., in the waste waters. At the low wholesale price of 5d. per gallon the savings effected amount to about £50,000 per annum. To these desirable ends the Milk Marketing Boards provided facilities for experiment and contributed £3,300 in cash.

To members of the Textile Institute the most interesting parts of this annual report are those relating to textiles. Reference is made to the extensions to the buildings at the British Cotton Industry Research Association. It will be possible to investigate the effects of atmospheric conditions on the weaving of silk and rayon. The growth of the staff of this Association is very briefly outlined and it is observed that the increasing appreciation by the cotton trade of the Association's work indicates that the present staff will not long be able to cope with the demands made upon it. The British Silk Research Association is making progress in its new surroundings and anticipates that it will be able to build rapidly on the foundations so securely laid at Leeds. The fundamental problem of correlating seriplane tests with the quantitative evenness tests for other textiles is one of prime importance.

The Wool Industries Research Association is exploring means for rendering more satisfactory the means by which its funds are raised. The shortcomings of the present system are fairly obvious and a lead towards the establishment of financial resources on an altogether sounder basis has been given by the statutory powers now available in Australia, South Africa and New Zealand for the collection of levies on exported wool. The importance of fundamental problems such as the quantitative estimation of the factors contributing to wool quality and the chemistry of keratin are still receiving attention. The proposal of a standard procedure for the determination of the fineness in tops was adopted by the International Wool Textile Organisation at its recent meeting in Warsaw.

The process for rendering wool unshrinkable by the action of gaseous chlorine is under trial on a semi-manufacturing scale and the release of the process is being considered. With such complicated problems as the causes of variability in the woollen carding process no immediate results can be expected.

The Linen Industry Research Association reports progress in its work on the production of flax and the development of the mechanical methods of processing. The experiments on the preparation and spinning of unretted fibre are of great interest. The collaboration between the Association, the Imperial Forestry Services and the Research Association of British Rubber Manufacturers provides an example of what should become increasingly common in the future. The growing interest of the trade in the Association and its work must be very encouraging to all concerned.

Considered as a whole this report of the Department of Scientific and Industrial Research proves that scientific research and its application in Britain and the Empire are in a flourishing state. If judgment by one's peers has still its ancient value, British scientists may be cheered by the report of their American brethren on the astrospectrographic object glass and collimator and prism system designed by the British Scientific Instrument Research Association. That this was described as " a truly remarkable achievement " is indeed high praise. T.

Knitting Full-Fashioned Hosiery. By Max C. Miller, M.E. Published by Mc.Graw-Hill Publishing Co. (259 pages 121 illustrations. Price 30/-.)

Mr. Miller in his preface states that he believes his book to be the only one of its kind in the English language and this is probably true for although *Die Cotton-maschine* (von E. Noble) was translated from the German into English it was never published in English.

In the course of 27 chapters Mr. Miller describes the mechanism, erecting and working of the " Reading " type of legging machine with meticulous care, discusses in detail the selvedge problems, the different forms of sutures and in his last chapter gives the trend of machine design during recent years. Hence there are only passing references to the " single unit " type of machine, split needle bars or pressers, three-corner cycles, single head machines, automatic welding apparatus etc., whilst apart from a chapter on " Mesh lace and picot " the production of fancy stitches is left alone.

What Mr. Miller has done however he has done exceedingly well and the book should be in the hands of all those connected with the full-fashioned hosiery industry. The knitting and fashioning movements are explained in full details whilst the chapters on selvedges and sutures are entirely new. The illustrations are a feature of the book and reveal the thought and skill expended. The arrangement of the matter is not strictly logical e.g. chapters XI and XII on erecting, aligning, assembling and adjusting the machine—sandwiched between the knitting and fashioning movements—should have been introduced earlier, along with chapter IV when a repetition of fig. 10 in fig. 50 would have been unnecessary.

There are very few errors in the book but on Page 1 " Lea " should read " Lee," and page 2, needle bars are now 15 inches wide. Mr. Miller mentions the jack on page 21 but not until page 150 does he reveal its purpose and even then does not mention the leverage. On page 9 he states in reference to the maximum width of the needle eye. " The measurement of the yarn must be taken with micrometers which *pinch the yarn considerably.*" This is a serious lapse from the scientific treatment he advocates.

The pre-Cotton inventors are not given justice on page 56 as the old rotary frames employed 4, 6 or 8 points not merely two as stated. Again the 6-phase fashioning diagram on page 70 is unnecessary in view of the 18-phase diagram on page 113. However these are small blemishes in a highly technical work treated in a thoroughly competent manner and it is hoped that during the next decade Mr. Miller will be able to produce its sequel wherein he will deal as throughly with the improvements which have been and are still continuing to be made as he has done with the standard legging frame of to-day. J.C.

British Association for the Advancement of Science. Report of the Annual Meeting, 1936, Blackpool.

The Wool Textile Sphere. G. F. Ashley. (7 bound volumes in typescript). These volumes have been acquired by the Library Committee from the executors of the late G. F. Ashley, Esq. During his long experience as a textile designer and salesman, Mr. Ashley collected and arranged the material in these volumes. The purpose of the work is indicated in the preface in which the author states that " the relation of one process of manufacture to another, of one section of a business to another, the combination of theory and practice and the examination of various problems from a broad point of view and in some definite order, deserve careful consideration, particularly by the younger generation, in these times of economic change". T.

Additions to the Library.

The following firms have recently brought up to date the issues of their catalogues which are available to members :—

Arundel Coulthard & Co., Ltd.—Winding and Spinning Machinery.

W. & T. Avery, Ltd.—Testing Machines, Weighing and Counting Machines.

Chas. Baker—Microscopes.

Fairbairn, Lawson, Combe, Barbour, Ltd.—Flax, Hard Fibre and Jute Machinery.

Sir J. Farmer Norton and Co., Ltd.—Bleaching, Dyeing and Finishing Machinery.

Gardinol Chemical Co.—Gardinol consists of the sodium salts of acid higher alkyl sulphuric acid esters. The Gardinol catalogues deal with the application of these compounds to the textile and leather industries. They contain also an account in simple language of detergent processes, contrasting soaps which undergo hydrolysis and the Gardinol products which give perfectly neutral solutions. Gardinol is resistant to lime and other alkalies as well as to acids. Its valuable properties are its wetting out power, emulsifying action, lathering power, and its cleansing and vivifying action.

Goodbrand & Co., Ltd.—Testing Machinery and Instruments.

Robert Hall and Sons (Bury) Ltd.—Looms.

Hanovia Ltd.—Ultra-violet radiation equipment and lamps for research, technical and industrial uses.

Thomas Holt, Ltd.—Winding and Warping Machinery.

John Jardine Ltd.—Lace Machinery.

Ernst Leitz—Microscopes.

Mather & Platt, Ltd.—Bleaching, Dyeing and Finishing Machinery.

British Northrop Loom Co., Ltd.—Automatic Looms.

Platt Bros., Ltd.—Cotton, Woollen and Worsted Machinery.

Prince-Smith & Stells, Ltd.—Worsted Machinery.

Siemens-Schuckert (Great Britain) Ltd.—Electrical Instruments and Equipment.

Universal Winding Co.—Winding and Warping Machinery.

Carl Zeiss, Jena—Microscopes and Accessories.

General Items and Reports

International Society of Leather Trades' Chemists

(British Section)

SYMPOSIUM ON SCIENTIFIC AND TECHNICAL ASPECTS OF WETTING AND DETERGENCY

Held 19th and 20th February, 1937.

A very successful Symposium on the above subjects, organised by the British Section of the International Society of Leather Trades' Chemists, was held in London in February. Two of the three sessions of the Symposium were of particular interest to the textile industry : the first, largely devoted to papers on the measurement of the physical constants needed in the quantitative study

of wetting and detergency; and the third, at which the papers read dealt with complications introduced into detergent processes by the structure of fabrics, and the chemical constitution and physico-chemical properties of textile fibres and detergents.

From the Dupré equation it can be deduced that the adhesion tension between a solid and a liquid can be calculated when the surface tension of the liquid and the contact angle (θ) it makes with the solid are known. Wetting, as H. Freundlich pointed out, is strong when the adhesion tension is large, i.e., when θ is small. A. Ferguson described a simple capillary-manometric method for measuring surface tensions of very small volumes of liquid, also applicable to the measurement of interfacial tensions of reasonable magnitude. An improved form of the tilting plate method of determining contact angles was put forward by C. G. Sumner in which the axis of rotation of the plate was arranged to be in the free surface of the liquid so that any displacement of the line of contact during measurement would be slight. An indirect, but more "dynamic" method of measuring the adhesion tension and the contact angle of a liquid against a finely divided solid, in which observations are made of the pressures set up by a liquid entering a mass of the powder in the form of a compressed block, is that of Bartell and Osterhof described by S. H. Bell, J. O. Cutter, and C. W. Price. The method of N. K. Adam and H. L. Shute for determining the contact angles made by fibres with detergent solutions was possibly of greater interest to textile chemists. These authors found that a fairly close correlation existed between the contact angle made by the oil-water interface with the surface of the fibre and detergent efficiency. This result emphasises the importance of the initial stage of detergent action during which the oil is displaced from the fibre, a process governed by the relative degrees of attraction of the fibre for the oil and for the detergent solution. These factors have been connected by N. K. Adam with the contact angle by an equation from which it follows, as Conmar Robinson emphasised, that no one factor, such as interfacial tension or surface tension, can alone decide the efficiency of a particular detergent. The essential conditions for efficient detergence are a combination of high solution-solid adhesion and a low oil-solid adhesion tension with a low solution-oil interfacial tension resulting in a contact angle of 0° or nearly 0°. This author found that the minimum concentrations of sodium oleate, sodium cetane sulphonate, and sodium cetyl sulphate necessary to give zero contact angles with lanolin-coated wool fibres fell into the same order as those required to remove completely a lanolin-lamp black mixture from wool serge. The magnitude of θ was apparently in some instances determined largely by the solution-oil interfacial tension, but in other instances by the solution-fibre adhesion tension.

The solution-fibre adhesion tension is modified by adsorption of the detergent. Both wetting agents and detergents are compounds of the paraffin-chain salt type, composed of a long hydrocarbon, oil-soluble, hydrophobic chain bearing a polar (either anionic or cationic), water-soluble, hydrophilic head: they are amphiphatic compounds (G. S. Hartley) having at the same time a *sym*pathy and ***anti***pathy to water. Soaps, sulphated and sulphonated fatty alcohols, as well as the quaternary ammonium detergents, all fall within this definition, although as H. K. Dean showed, the long, hydrocarbon chains of some of the newer wetting agents and detergents may contain double bonds, imino groupings and even ring systems, each compound exhibiting a particular "balance" between the hydrophobic characteristics of its organic tail and the hydrophilic characteristics of its polar head. In wetting, the hydrophobic portions of the molecules become buried in the hydrophobic surface (or dirt on the surface) with their hydrophilic, polar heads exposed to the water. E. K. Rideal summarised the evidence which suggests that in detergence, the polar heads of the molecules penetrate and form loose complexes with the films of molecules on the "dirty" surface; these complexes being displaced when the detergent is adsorbed on the surface. In an

apparatus described by R. C. Palmer, it was found that the number of hydrophobic particles remaining attached to the hydrophobic upper surface of a cell gradually decreased as the concentration of the detergent solution in the cell was increased, the minimum in the "adhesion number" being obtained when the cell wall and the particles were covered with a packed monolayer of detergent.

The newer detergents with strongly polar heads ($SO_2.OH$; $O.SO_2.OH$) show particularly strong penetrative powers. As emphasised by E. T. Williams, C. B. Brown and H. B. Oakley, the chemical reactivity of the fibres to be cleaned may also influence the amount of detergent adsorbed and rendered inert. The structure of wool fibres, for example, is loosened by acid and alkaline solutions, particularly at temperatures exceeding 40°C. In addition, the amount of detergent adsorbed will depend on its polar character : the anionic detergent Igepon being adsorbed by wool on the acid side of its iso-electric region, whilst the cationic detergent Sapamine is adsorbed on the alkaline side of its iso-electric region. Experimental cleansing of soiled fabrics in dilute solutions of these detergents at different *p*H values, and also at temperatures exceeding 40°, indicated that increased adsorption of the detergent decreased the detergent efficiency of the solution. The addition of sodium chloride suppressed the swelling of the wool fibres and thereby decreased adsorption and improved detergence, whilst a less polar detergent—a polyglycerol ester—was found to retain its detergent efficiency over a wide *p*H range. The adsorption of detergents by textile fibres, particularly wool, is sometimes desirable because it improves "handle." H. Phillips suggested that not only the newer detergents, but also soaps may be adsorbed in the interior of wool fibres from soap solutions which are sufficiently dilute and may partly determine the degree of fibre breakage during carding. J. Powney emphasised that under industrial conditions, the adsorption of the detergent caused progressive and indeterminate changes in the concentration of detergent solutions during the penetration of a fabric, and hence detergent efficiency was partly dependent on the relative rates of diffusion of the solution into the capillaries of the fabric and the adsorption of the detergent on the fibre surfaces. The inter-fibre capillaries were also full of air, the displacement of which was favoured by mechanical disturbance and by increase of temperature. The author described an apparatus for determining the rate of penetration by measuring the change in electrical resistance of a fabric being penetrated by a detergent solution from two opposite sides.

Most of the papers were thus concerned with very dilute solutions of detergents. The mechanism of the emulsification of oil and grease after displacement from surfaces was, however, also discussed. In dilute detergent solutions, the hydrocarbon chains of the detergent can be considered to become embedded in the displaced oil and to expose their polar heads to the water. In more concentrated detergent solutions, G. S. Hartley pointed out that the detergent (paraffin-chain salt) formed aggregates or micelles in which the hydrocarbon (paraffin) chains were orientated towards the centres with their polar heads outwards. The inner portion of such a micelle could be regarded as a droplet of liquid paraffin capable of dissolving organic substances. For this reason, many organic substances were more soluble in solutions of paraffin-chain salts than they were in water. The common practice of removing stains by saturating the fabric with oleic acid which was then washed off with alkali makes use of a concentrated solution of sodium oleate as a solvent. The addition of an amphiphatic non-electrolyte, such as cyclohexanol, to a soap solution may result in the formation of mixed micelles in which the hydrocarbon portion of the cyclohexanol molecules are orientated in the same manner as the paraffin-chain ions from the soap. Since the solubility of a non-electrolyte in water can be increased by a paraffin-chain salt, it is a necessary thermodynamic consequence that the non-electrolyte will increase the solubility of the paraffin-chain salt. The increased solubility of a soap resulting from the addition of a non-electrolyte may therefore prevent its

precipitation in hard and salt waters. An alternative mechanism for the action of non-electrolytes was proposed by A. S. C. Lawrence, who considered that they were molecularly dispersed and acted as peptisers which prevented the aggregation of the primary micelles formed by the soap.

The papers given at these two sessions of the Symposium thus covered many theoretical and practical aspects of wetting and detergency. They will be published in book form and will constitute an up-to-date account of modern views on these subjects and the methods by which they can be investigated.

H. PHILLIPS.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

International Congress, 19th-24th April, 1937

The programme of the London Congress contains matter of interest to makers and users of materials of all kinds. It is difficult to conceive that anyone could attend the Congress without acquiring valuable knowledge of the properties of materials and their testing.

The papers of major interest to those engaged in textiles are the forty-five which appear in Group C. The nine papers on textiles deal with wear testing, chemical and mechanical tests, colour fastness, damage to rayon in processing and the properties of fibrous materials when used as a reinforcing layer in building materials and insulating bodies. In addition there are ten papers on wood cellulose, ten on timber preservation, nine on the ageing of organic materials and seven on colours and varnishes.

Group D, which is also of some considerable importance to the textile industries is divided into :—

Sub. Group 1. Relation between the results of laboratory tests and behaviour in use and service. (6 papers.)

Sub. Group 2. The bearing of recent advances in physics and chemistry on the knowledge of materials. (7 papers.)

Sub. Group 3. The properties of materials for the thermal and acoustic insulation of buildings. (12 papers.)

Participation in the Congress will be open to all interested in the study of materials and their testing on payment of the membership fee. Ladies accompanying members of the Congress are cordially invited to take part in the Plenary Sessions and all excursions, and to attend the Reception by H. M. Government, the Banquet, the Dance, the Soirée by the Royal Society, and the Entertainment by the British Broadcasting Corporation.

Membership Fee (applicable only before 31st March, 1937—No Fee payable by a Lady accompanying a Member)—£1. 1s. od.; after 31st March—£1 10s. od.

All further particulars may be obtained from the Organising Secretary, 28 Victoria Street, London, S.W.1.

THE INSTITUTE OF PHYSICS

Second Conference on Industrial Physics

Birmingham, 18th, 19th and 20th March, 1937.

The subject of the Conference was " Optical Devices in Research and Industry." The programme included in addition to the Presidential Address by Prof. A. Fowler, F.R.S., on " Spectroscopy in Industry," the following lectures and discussions.

(1) Colorimetry, Spectrophotometry and the Inspection of manufactured products for " Appearance."

(2) The Application of Electron Diffraction to Industrial Problems.

(3) Industrial Uses of Photocells.
(4) Optical Gauges for Metrology and Engineering.
(5) Polarimeters, Saccharimeters and Refractometers in Sugar, Jam-boiling and other Industries.

The first of these was of the greatest interest from the textile point of view. The lecturer (Mr. R. Donaldson, M.A., of the National Physical Laboratory) discussed the broad principles of colorimetry, showing how the complete analysis by means of the spectrophotometer of the light from a coloured object is linked up with the three coefficients necessary to specify the colour on the trichromatic system. The possibility and desirability of a photo-electric colorimeter was mentioned and the difficulties, inherent in the design of such an instrument were enumerated.

The discussion brought out many points of great practical interest and importance. That the available colorimeters give indications of the highest utility was not challenged, but reference was made to numerous conditions under which the instruments are only partially successful. The replies to questions regarding the quantitative measurement of the numerous "whites" and the hundred or more shades of "black" were that these constituted "special problems" in colorimetry. The need for limiting the number of shades and for an official and authoritative shade card was stressed from more than one quarter. The fixing of the magnitude of the step from shade to shade is a very difficult problem. The results obtained from colorimetric observations seem to depend in a complicated fashion upon the intensity of the light incident on the coloured objects, which may be partly a physiological effect. The difficulty introduced by the effect of the degree of roughness of the surfaces of the coloured objects, typified by the difference in appearance between a satin and a crape of the same material dyed in the same bath, is not overcome by the stipulation that the surface is to be illuminated by light incident at 45° and viewing to be normal.

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXVIII APRIL 1937 No. 4

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

Council Meeting, 14th April, 1937

This meeting, which was held immediately prior to the Annual Meeting, dealt with routine business and then dealt with matters of interest to members generally. It was unanimously agreed to award the Institute Medal for their services to the Industry and the Institute in particular to Mr. John Emsley of Bradford, a past-President and prime mover in securing the Institute's Charter, and to Mr. W. H. Webb of Randalstown, for many years Chairman of the Irish Section Committee. These awards will be made at the Annual Conference at Southport. The addition of these names to the already distinguished list of recipients will, it is believed, be generally approved.

The Honorary Secretary, Mr. F. Nasmith, as Chairman of the Conference Committee, reported progress in regard to Conference arrangements at Southport. By the time this note appears all members will have received a Preliminary Announcement and Attendance form relating to this event. It can be added that even now a good record of bookings has been received and the general interest shown in the Conference Subject—The Serviceability of Fabrics for Clothing Purposes—is notable. Good progress has been made with the Exhibition arrangements and an attractive and informative display can be anticipated. Mr. Nasmith also referred to a meeting of representatives of the Press which had been held in the previous week and which had been well attended.

Mr. Henry Binns, speaking for the Bradford Textile Society, presented the Institute with a manuscript work on "Colour: an analysis of the characteristics and relationship of Colours as a basis of effective Composition" by the late Mr. G. F. Ashley of Bradford. This work had been aquired by the Society but had been thought to have been more suitable for inclusion in the Library of the Institute: this gift was the result of the Society's decision to that effect. The Society further increased the value of the gift by offering to cover the cost of binding of the manuscript. Mr. Jaques thanked Mr. Binns and on behalf of the Council accepted the presentation with real appreciation of its value. When bound the volume will be available for consultation in the Library. It is possible, however, that some part of the work may be published; this aspect of the matter was referred to the Publications and Library Committees.

A full report of the Annual Meeting appears in this issue on pages P80 to P84.

Obituary Notices

The Institute has recently lost, by death, two distinguished and valued members: Sir James Currie and Mr. John Tattersall. Sir James died on the 17th March and Mr. Tattersall on the 18th April. Mr. Tattersall went to Holland at the age of 26 and eventually built up the big business at Enschede in connection with which his name was known throughout the Textile world. His activities spread to Amsterdam and later to Brazil and his inventions were numerous, and in several instances of real importance to the industry. From the Queen of Holland he received the Order of Philip of Nassau, the highest order that civilians can receive in Holland. He also received the Order of Leopold the Second and was recognised and honoured in many other ways. At the age of 85 he was elected a Fellow of this Institute, a recognition which he much appreciated.

Sir James Currie, K.C.M.G., K.B.E., was born in 1869, and educated at Fettes and at Oxford, where he was a Scholar of Lincoln College. He represented the University against Cambridge at golf in 1889. From 1900–1914 he served in the Sudan as Principal of Gordon College, Khartoum, and Director of Education. For the last four years he was a member of the Governor-General's Council, and twice acted as a Governor of a Sudan Province. During the War he was Director of Training of Munition Workers at the Ministry of Munitions, and subsequently became Controller of the Industrial Training Department, Ministry of Labour. In 1921 he was appointed Director of the Empire Cotton Growing Corporation, where his previous experience in the Sudan, which has now become one of the most important cotton-growing countries with which the Corporation deals, stood him in good stead. It was Sir James's responsible task in the early days of the Corporation to suggest to the Executive Committee the lines upon which its policy should be laid down, and it is largely due to his wise foresight that the Corporation recognised from the first the necessity of training up a scientific staff of its own, and continually laid stress on the importance of a knowledge of fundamental principles in all those who had to deal with the development of any form of tropical agriculture. Before the Corporation was formed, the British Cotton Growing Association had been at work for nearly 20 years, and since 1921 the Association and the Corporation have worked in the fullest co-operation. Sir James devoted a considerable proportion of his time to other public services, which in one way or another had a bearing on the Corporation's aims and objects. He was Chairman of the Overseas Mechanical Transport Directing Committee, a member of the Colonial Office Advisory Committee on Native Education, and of a Committee appointed to enquire into Agricultural Education in Great Britain and of another Committee recently appointed to enquire into Veterinary Education.

TEXTILE INSTITUTE DIPLOMAS

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (February issue of this *Journal*) :—

FELLOWSHIP

GOODALL, James Robert Sergent (Manchester).

ASSOCIATESHIP

DORMAN, Hugh James (Dundee).
FULLARD, Herbert (Wigan).
SPEAK, Frank (London)
SWAN, Enoch (Bolton).

Employment Register

The following announcements are taken from entries in our Register of members whose services are on offer. Employers may obtain full particulars on application :—

No. 157—Young man, requires position as Assistant Manager of Silk Throwing Mill or similar position in Silk Manufacturing. City & Guilds' Final in Silk Manufacture and Drapers' Scholarship. Ten years' experience in Manufacturing. Two years Assistant Manager in Silk Throwing Mill. Age 25 years.

No. 158—A.T.I. requires position as Spinning Master or Inside Manager. Experience in all qualities, Twist, Weft and Hosiery Yarns, Cotton, Wool and Artificial Silk mixtures. Prepared to go abroad. A.M.C.T. Age 30 years.

No. 159—Requires position as Wool Buyer, preferably in carpet trade or Assistant Mill Manager. City & Guilds' Full Technological Certificate in Woollen and Worsted Yarn Manufacture. Prepared to go abroad. Five years' experience in sorting all classes of wool. Age 27 years. A.T.I.

No. 160—Applicant age 26 years desires position as Salesman or Assistant to Director with fine Worsted Spinners. Prepared to go abroad. City and Guilds' Full Technological Certificate. Knowledge of French and German. Nine years' experience with Bradford firm of Worsted Spinners.

Institute Membership

At the *April* meeting of Council, the following were elected to Membership of the Institute :—

Ordinary :

Harold H. Catterall, B.Sc.Tech., 10 Nansen Road, Gatley, Cheshire (Departmental Manager, The Harrison Knitting and Textile Machinery Co. Ltd., Manchester).

Ernest Farrell, Clowes Street Engineering Works, Chapel Street, Salford, 3 (Engineering Employer).

John Flint, 526 Higginshaw Lane, Oldham (Cotton Mill Manager).

A. P. Mieras, B.Sc., A.I.C., 22-28 Beaverhall Road, Edinburgh (Laundry Managing Director).

I. F. Raphaely, c/o The Standard Woollen Mills, Ltd., Harrismith, O.F.S., South Africa (Factory Manager).

George A. Ross, 49 Botanic Avenue, Belfast (Traveller and Textile Student).

John Richard Stenson, The Kaleeswarar Mills, Ltd., Coimbatore, South India (General Manager).

George H. Wood, Greystones, Bingley, Yorkshire (Secretary, Woollen and Worsted Trades Federation).

Junior :

M. H. Bell, 2 Park Range, Victoria Park, Manchester, 14 (Textile Student).

T. F. Gibbons, B.Sc.Hons., 22 Gotham Street, Leicester (Works Chemist, Dyeing and Finishing).

TWENTY-SEVENTH ANNUAL MEETING OF THE INSTITUTE

Meeting held at 16, St. Mary's Parsonage, Manchester, Wednesday, 14th April, 1937.

Mr. Wilfred Turner, President of the Institute, took the Chair and called on the General Secretary to read the list of apologies. These included a letter from Mr. John Emsley, past-President, congratulating Mr. John Crompton, President-elect, on the honour to be conferred upon him.

The Minutes of the previous Annual Meeting, held on the 22nd April, 1936, were read, approved and signed.

The Council's Annual Report, already circulated to members in the March issue of the *Journal*, was adopted.

The Hon. Treasurer, Mr. W. W. L. Lishman, presenting his report on the financial position of the Institute, said:—

"Again I have pleasure in presenting my report as your Honorary Treasurer. I think you will agree that this need only be short as you will all have had the opportunity of reading Council's Annual Report in the current issue of our *Journal*.

"During the year we have had rather heavy expenditure from causes over which we had no control. Nevertheless, I feel, as do my colleagues on the Finance Committee, that this expenditure has been warranted for more reasons than one. I should like to point out that with the growth of Membership experienced, which has been very gratifying to all of us, we have been able not only to maintain the usual work of the Institute but to meet new demands made upon us.

"Unfortunately, the serious illness and subsequent retirement of Mr. Athey deprived us of his services throughout the year, and this has involved additional expense on our staff Account. The provision of his pension in the current year will make a continued demand on this Account.

"I am pleased to report that we have been able to fix up two gentlemen to fill the offices of General Secretary and Technical Editor—Mr. Robinson and Mr. Hall—on favourable terms. I am hoping that in this direction we shall have many years of their services.

"At this point I should like to thank all the members of the Staff for their work during the past year, and particularly for the help given to me. I must also thank our Auditors, whose work on our behalf merits general commendation.

"The National Certificates scheme, which I mentioned in my last report, is still going forward in a satisfactory manner so far as its finances are concerned. The Foundation Fund continued to be a source of strength. We feel that all our investments have been made well and soundly.

"My report to you would be incomplete if I did not record my personal thanks to our Honorary Secretary, Mr. Frank Nasmith, for the help he has always readily afforded me."

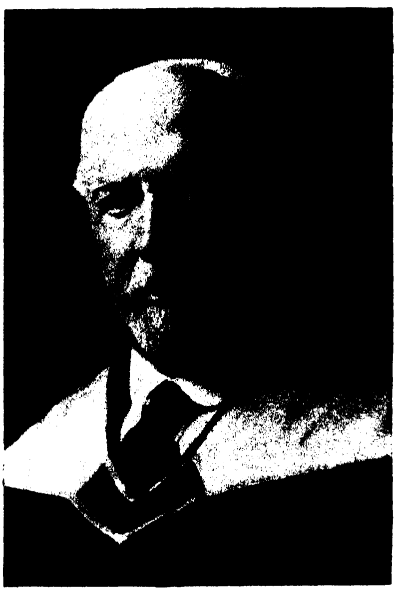
The Auditors' Report, Balance Sheet and Accounts for 1936, as already printed in the March issue of the *Journal*, were adopted on the motion of the Hon. Treasurer.

The President then proposed the election, as new President, of Mr. John Crompton, O.B.E., M.Sc. (Tech.), F.T.I., of whom he said he had heard the highest commendations from all sides. Past Presidents of the Institute had expressed to him their appreciation that this honour should be conferred upon Mr. Crompton. He would add that he heartily endorsed these sentiments and believed that the Institute honoured itself in honouring Mr. Crompton, whose record of service to the industry and the Institute was well known to all. He called upon Mr. F. C. Porter to second the proposal. Mr. Porter made reference to the long service Mr. Crompton had given to the cause of technical education

through the Union of Lancashire and Cheshire Institutes and the City and Guilds of London Institute. On being put to the meeting, Mr. Crompton was unanimously elected with acclamation and inducted to the President's Chair by Mr. Turner, who presented him with the President's Badge of Office. Addressing the meeting, Mr. Crompton said :—

" Remembering the fact that I am one of the Foundation Members of this Institute, its Chairman during the years 1922-28 and also that during the past twenty-five years I have endeavoured to render unstinted service ; you can well understand that to-day I feel a degree of pride that I have so far retained your confidence as to be asked to become your President.

" I appreciate the fact that our esteemed retiring President, Mr. Turner, is with us, and has performed his part of the proceedings with that grace and charm which personify all his actions. I fully realise that I follow a succession of Presidents who have been great men in the textile world.



Mr. JOHN CROMPTON
Elected President, April 1937.

" It will be my endeavour to carry forward, with equal enthusiasm and dignity, such influences as shall not only uphold past traditions, but also develop new avenues of service. I take office fully confident that the officers of the Institute will continue to render efficient and faithful service, and I would like to take this opportunity of acknowledging the self-sacrificing labour of so many Chairmen and Members of Committees who have won our esteem. The Institute has always been blessed with a competent and attentive staff, prepared to render of their very best and do their work with promptitude and efficiency. May I also remind you of the devoted labours in years gone by of Mr. Athey, Mr. Frost, Mr. Fletcher Robinson and many others now no longer with us.

" As you are aware I personally have been particularly interested in the Institute's activities regarding the encouragement of textile design and fabric structure about which it is generally agreed that our prize scheme, together with our issue every year of albums of modern typical fabrics, has been a decided success. The generous bequest of £1,000 by the late Mr. R. J. H. Beanland of

Clayton West, Huddersfield, has enabled the Textiles and Designs Committee to add two new Competitions to those already well-established. These new competitions, in accordance with Mr. Beanland's expressed wishes, relate to worsted fabrics. This is the first year of their inauguration and it can be said already that entries for these competitions are coming in well.

" The Institute welcomes the proposal to establish in Manchester a regional College of Textile Art to be controlled in close collaboration with the College in London; and our hearty co-operation can be relied upon.

" It must be a matter of satisfaction to those concerned with the educational aspect of our work that the Board of Education, having been urged to establish National Certificates in Textiles, should have invited the co-operation of this Institute in the conduct of the Scheme. This work has now been proceeding for sufficient time for at any rate a preliminary view of the situation to be formed. It must be a matter of no small gratification to those representatives of the Board and of this Institute who form the Joint Committee in charge of this Scheme that it has gone ahead so well in so short a time.

" I take this opportunity to express my admiration of the painstaking and valuable work of two important educational bodies. I refer to the Union of Lancashire and Cheshire Institutes, and the City and Guilds of London Institute with whom I trust our Institute will always labour in close co-operation.

" These worthy Institutions have for the past half-century encouraged technical education to such a degree, that had it not been for their efforts the manufacturers of Lancashire would not have found an educated body of young men ready to undertake the change-over from grey calicos to the widely varied crepe-de-chine or satin rayon fabrics now required for our home-trade and colonial markets.

' It gives me great joy to remember that I have been personally associated with both these bodies for fifty years. Although it is true that one-third of Lancashire's pre-war looms are either broken to pieces or standing idle, I still hesitate to become a pessimist, and I like to visualize the possibility that, in spite of the fact that South America, India, Japan and many other countries, are now largely independent of supplies from England, we may so develop the quality of our textures that overseas nations will again demand our manufactured goods in exchange for their natural products.

" The recent display of fabrics at the British Industries Fair should convince the most fastidious that England can produce the goods, but to my mind the unfortunate feature at present is that many manufacturers fail to be sufficiently firm in the prices they quote. Whilst they are ultimately compelled to cover for advances in cotton and wages, sufficient margin ought to be secured to provide a fair return on the capital at stake, and a satisfactory allowance to cover depreciation and possibly necessary replacement by more modern machinery.

" As an Institute it has always been our endeavour to encourage both scientific and practical mill management, and to train young men so that by proper methods they can ascertain the actual cost of production, no matter how complicated the processes of manufacture. Our young managers must also have unprejudiced minds regarding new developments or inventions, such as the fuller application of the pneumatic principle in the " blowing room " of the spinning mill, or automatic appliances in weaving.

" It is my firm conviction that in spite of the advancement of technical education during the past thirty years, the last big revision of weavers' wages was approached with almost as little scientific study as when weaving prices were first fixed by certain rigid rules. As a consequence, by merely adding percentage rates of increase to price lists already containing many anomalies a previously unfair deal to the weaver was intensified. The opportunity should have been taken so to revise and adjust the basis of weaving prices that all weavers should be able to earn satisfactory wages according to the actual labour

and skill involved. I also maintain that not sufficient cognizance was taken of mechanical aids to weaving, such as automatic warp stop motions. No matter whether any mechanical process is controlled by a private firm, or by the state, if it is considered wise to adopt labour saving devices as an economy of the operatives' time or energy, then it should be a matter of sound argument as to what proportion of the saving should be credited to the provider of the apparatus and what proportion to the operative.

" It must be the aim of the Textile Institute so to encourage research and invention that as much as possible of human drudgery is eliminated from textile processes. To this end the improvement in recent years in the freedom of textile yarns from weak places, the introduction of large conical packages of yarn, and reduction of friction during winding and warping, and the consequent freedom from slubs and clumsy knots ; have all caused less breakage of warp and weft threads during the process of weaving.

" Improvement in the method of sizing, and the ingredients used, is worthy of continued research, as the prevention of broken threads not only saves trouble to the weaver but makes a more perfect fabric possible. The degree to which the weaving qualities of rayon have improved in recent years is very creditable to the producers, and when a properly-adjusted loom is used rayon is often less trouble to the weaver than cotton. If further careful experiment in the spinning of staple fibre results in equal improvement then the weaver will be very thankful.

" I have every sympathy with the worker, and I am in favour of restricting the length of the working day. Increased leisure calls for sound judgment as to how best to spend it, and I strongly advocate participation in games or in such interests as horticulture and gardening. If, however, increased leisure is secured by improved automatic machines at probably high cost, it would be the height of folly to limit the operation of such machinery to, say, a 40-hour week.

" I have in mind, for example, an automatic loom costing £200, which, at 10 per cent. interest and depreciation, would first have to earn £20 per year or 8/- per week to justify the outlay. If however, this loom is worked two shifts or a total of 80 hours per week, then each period would only have to contribute 4/-, a saving in which the operative could reasonably ask to share. How nice it would be to be free for games or the garden from say 2 p.m. to bedtime in long summer days, certainly worth the effort of rising alternate weeks at 4.30 a.m. or 5 a.m.

" I certainly believe that the workers should receive an ample share of any wealth created by improved mechanism, but surely it can be realized that the initial cost of the machine must first be provided for.

" Many persons who argue against automatic machines seem only able to visualise a possible reduction in the number of operatives, and appear to forget that the manufacturer of these machines finds employment for a large number of machinists besides helping towards the retention of our trade.

" Although this is termed an age of the mechanisation of industry, I personally do not see any reason why it should not prove to be the best period for industrial workers of any yet experienced.

" In attempting any general survey of the textile industry I should be greatly lacking if I failed to stress the fact that the treatment of fabrics after they leave the loom is to-day a more important feature than ever before. The good old days when the clever cloth finisher doubled the weight of a fabric without entirely destroying the texture, or raised such a splendid nap on cotton goods as to persuade the unwary that they were wool, have no doubt gone, but to-day the weaver, dyer, printer and finisher must co-operate to the fullest extent possible if smart, soft-feeling, crease-resisting, beautiful draping and elegant furnishing fabrics are to result. This essential co-operation, makes the Textile Institute indispensable. By our monthly *Journal*, frequent conferences and suggestive investigations, we link up every distributor and wearer of the finished product.

"It has been a great satisfaction in recent months to find that enlightened laundry managers are becoming members of our Institute in large numbers, because they realise the laundry industry has much to learn, and must be in the van of progress by co-operative effort.

"Already a notice has been issued to the Press regarding the agreement reached by this Institute and the British Standards Institution in regard to the preparation and publication of Unified Methods of Testing. It is confidently expected, by the Committee in whose hands this work has been placed, that this undertaking will be of real and lasting benefit to the Industry as a whole.

"In this connection, as indeed in connection with the whole of the Institute's work, it is my duty and pleasure to express publicly our indebtedness to the Directors and Staffs of the Research Associations for the Cotton, Wool, Linen and Laundry Industries. In our Diploma work, in our *Journal*, and now in this matter of the Unification of Testing Methods, their advice and collaboration is freely given: we can assure them that it is appreciated.

"Announcement has been made in regard to our Annual Conference at Southport this year, and documents relating to the event will be in the hands of all Members this week-end. The subject for general discussion, that of the Serviceability of Textile Fabrics for Clothing Purposes, is, I need hardly say, one of very real importance to the trade. I look forward to a successful gathering and urge all members and friends to attend and contribute so far as lies in their power, to the success of the Conference.

"The stage is set for continued progress and development. That this may soon materialise, and the textile industry revive is my earnest desire."

The newly-elected President then moved from the Chair that the best thanks of the meeting be given to the retiring President, Mr. Wilfred Turner, for his services in that capacity. This proposal was carried with enthusiasm.

Mr. Fletcher Chadwick proposed and Mr. W. Scott-Taggart seconded the re-election of Messrs. H. Binns and Frank Wright, and the election of Mr. S. E. Ward as Vice-Presidents. This was carried unanimously.

The Scrutineers' certificate as to the ballot for Council was presented and the President declared the following results:—

Elected:—Barnes, H. C. (Manchester), Chadwick, F. (Preston), Davis, William (Nottingham), Greenwood, H. (Bury), Howarth, William (Bolton), Lishman, W. W. L. (Todmorden), Nisbet, H. (Manchester), Stevenson, A. W. (Galashiels), Wildt, E. (Leicester), Wilkinson, William (Blackburn).

Not elected:—Hanton, W. A. (Manchester), King, W. E. (Bradford), Wood, F. C. (Manchester).

Messrs. Arthur E. Piggott, Son & Co. were unanimously re-elected auditors. Mr. I. Piggott, on behalf of the firm, thanked the meeting and expressed satisfaction with the Institute's financial position.

Proposed by the Hon. Secretary, Mr. F. Nasmith, and seconded by the Hon. Treasurer, a unanimous vote of thanks was expressed to the staff for their services in the past year.

London Section

At a meeting of the London Section of the Textile Institute at the Hotel Victoria, London, on the 5th February 1937, the following lecture on " Textile Defects and other problems which confront the Making-up Trade ", was delivered by Mr. G. N. Warnock. Mr. T. C. Petrie, chairman of the London Section, presided over a good attendance of members and visitors.

Mr. Warnock said : The subject I have chosen covers an extensive ground. It is, furthermore, in the nature of an experiment, since it has been arranged that manufacturers shall reply to the points raised. Thus, manufacturers will perhaps gain a fuller appreciation of the consumers' difficulties, and the consumer be given a greater understanding of manufacturing problems. The great point is that the producer and the consumer will be given the opportunity of meeting for discussion on common ground. If both parties are willing, only good can come from such an encounter. We must seek ways and means of surmounting our difficulties, if wastage in material and labour is to be eliminated.

It is my duty to be a critic, and I gather that I must be as provocative as I can, without being actually offensive. A buyer, by the very nature of his vocation is more frequently called upon to be a critic than a creator, but personally, I have little use for criticism that is solely destructive. Consequently, I have endeavoured to show how certain difficulties might be overcome. It will be for the manufacturer who is to reply, to demonstrate the impracticability of any of these suggestions, and to put forward alternative remedies.

Survey of the Growth of the Making-up Trade.

At this stage a very brief historical survey of the growth of the making-up industry may be helpful. This will enable those among you who are not familiar with the trade to understand the position more clearly, while the remainder may have their memories refreshed. A tremendous advance has taken place in this industry, in common with many others in this age of specialisation.

Before the war, the position was briefly as follows. A youth was apprenticed to a maker-up, and received a thorough training. Having attained sufficient experience over a period of years as an employee, and secured some degree of financial backing, he would begin in a small way as an outworker ; that is, he received cloth, lining, etc., from a firm, made the coats, and returned them to that firm. He received payment for making the garments. When he had paid his work-people and rent, the balance represented his profit. He had no liabilities or risks as regards cloth commitments or stocks. He had no worries of distribution, involving the additional expense of showrooms and representation. He was, purely and simply, a master tailor. After the war, many of these master tailors began their own businesses and controlled their own buying and selling, as well as manufacturing activities. The principals held all the reins in their own hands—they bought, made, and sold. Cloth buying was done by experience of how various cloths would make-up, plus a flair for fashion, rather than by a technical knowledge of textiles. Many businesses are still carried on in this way. Other firms have adopted scientific methods of production. In some instances, these methods are in advance of those obtaining in the men's multiple clothing factories, although of course, in the ladies' trade, mass production on such a scale is not possible for the following reasons :—(1) The short duration of seasons ; (2) The marked contrast in seasonal requirements ; (3) The element of fashion ; (4) The vast variety as regards colours and types of cloth, and (5) The styles of garments required.

Costing, once a very haphazard estimate, is to-day on an accurate basis. Instead of relying on the annual audit, to determine whether the year's trading shows a profit or a loss, reliable departmental statistics give the position week by

week, and even day by day. One of the chief results of this specialisation has been the exposure of what were formerly "invisible" losses, either through theft, carelessness, or other causes. Again, the figures can now tell whether a given cloth has been satisfactory or not. To give an example, the report on cutting may show a loss of 25 yds., on the cutting of 200 coats. An explanation must be sought to account for the discrepancy. It may be found that a number of pieces were narrow in width, say 52″ instead of 54″, and had inadvertently been passed into stock. As a result, the pattern could not be fitted into the costed coat-length of say, three yards, and that while the costing was made out for this amount, the yardage actually required may have been 3⅛ yds. Thus on 200 coats, there is a loss of 25 yds. in material. If the cost of the material is 4/- yd., the actual loss at the very first stage of manufacture is £5. This, of course, is a simple example of how statistics can bring to light discrepancies which would not otherwise be brought to the notice of those whose responsibility it is to supply the works with material which is up to standard in every respect. The existence of such methods has put buying on a more scientific basis than ever before. When a cloth is bought to a specification, it must come up to that specification.

Manufacturers should see to it that they adhere to all the conditions given on the order sheet. Take a cloth ordered on the following terms :—

All Wool Velour, design and finish as sample.
54″ between lists, 16 ozs., at 4/- yd.

It should be realised that 15 ozs., will not do, and that the cloth will not condition from 15 to 16 ozs. per yard, though the faith of some manufacturers in the wool fibre's power of absorption is a thing beautiful to contemplate. "All wool" does not mean 15 per cent. cotton, whether scribbled or otherwise—nor can 52″ or 53½″ be accepted as 54″ within lists. If only manufacturers would realise these points, no end of returns would be avoided.

No piece should ever be passed into stock until tests have been made to ascertain the following points :—

1. Weight.
2. Width
3. Warp and weft strength.
4. That the shade is as ordered.
5. That the piece is free from listing.
6. That the finish compares favourably with the sample.
7. That the price is correct.
8. That the yardage is accurately stated.
9. That the faults are strung.

Owing to the difficulty of perching and re-blocking woollen and worsted pieces, the last two items of yardage, and indication of faults have usually to be taken for granted, until the pieces are in the hands of the cutters. Of course, any serious discrepancy in yardage will be shown up when the weight is being ascertained. I look forward to the time when makers-up will have their own testing departments, and when it will be possible to perch and measure each piece before it is accepted. I am convinced that the time will come sooner or later. It will be an economic success for those who install such plant. What is even more important, such a step would have an immediate and valuable effect in raising the standard of all textile productions.

The Chief Causes of Textile Imperfections.

All defects arise from one or other of the following causes :—

(1) Imperfection inherent in the raw materials of production, and which our technology has not yet enabled us to overcome.

(2) Forces over which we have not got absolute control, such as atmospheric conditions, mechanical forces, etc.
(3) The failure of the "human element," or, to put it more bluntly, carelessness or neglect.

More than 90 per cent. of the faults can be placed in the last category, and I could tire you by quoting hundreds of examples of imperfections that have been caused through sheer carelessness on the part of operatives. Allow me to give you only one example. A mill was making a large quantity of cream velours, and elaborate measures had been taken to ensure the high standard of cleanliness necessary for this product. Despite all precautions, piece after piece, was found to contain peculiar brown stains. First of all, rust was suspected, and all the metal in the mill was carefully examined, but the pieces continued to be stained as before. Finally and purely by chance, it was discovered that a certain employee had a fondness for chewing tobacco. It so happened that he was stationed near the hydro-extractor, which appeared to him to be a spittoon "par excellence." At regular intervals he would expectorate into the wool, thus imparting to the blend the regularity of imperfection which was so baffling to the investigators.

With regard to textile production, there are two points of view, first, that of the consumer, who maintains that he pays for perfect goods, and second, that of the manufacturer, who holds that textile imperfection, like poverty, will be with us to the end of time, and that the buyer can expect nothing else. That these extreme views require to be modified, is obvious. The buyer must expect a certain amount of imperfection, but it is also incumbent on the manufacturer to eliminate all faults that are caused through carelessness, and to install a more satisfactory system of supervision than obtains to-day. Further it is his duty to the consumer to see to it that all faults, however slight, are clearly indicated. This is the least he can do, and while I am prepared to admit that there will be a number of flaws in any piece, I cannot possibly condone negligence in stringing these faults, so that they can be avoided when the material is made up.

Worsted.

As far as the ladies' trade is concerned, the worsted industry has, for a number of years, been under a cloud, from a fashion point of view. Now that the prices have advanced with such startling rapidity, it is all the more difficult for the manufacturer to keep his plant employed.

The chief defects in worsted cloths are weaving faults, ends down extending for anything from ¼ yd. to 1½ yds. One would think that for cloth of this nature, the expense of installing automatic stop looms would be well covered by the saving of labour in burling and mending. In worsteds, weaving is of primary importance, since it is the weave that sells the cloth and the slightest fault is shown. Weft bars are common, and there are far too many oil stains. These are obviously from the loom, yet such is their tenacity that they are not removed in the subsequent scouring, dyeing and finishing processes. Cloths where crêpe yarns are employed are difficult to produce. Variations in figure and shrinkage give rise to endless complaints, either in regard to the appearance or to the subsequent working of the cloth.

On one occasion, I was shown a sample of "backed georgette" which had a particularly good finish. The pieces, however, were so devoid of figure as to be scarcely recognisable. I attacked the dyer, and eventually discovered that the manufacturer had given instructions for the finished length of the pieces to be increased by 1½ yds. A saving of 6/- per piece was thus effected at my expense, and the cloth was ruined. Needless to say, the contract was cancelled, and business relations were abruptly terminated. Such experiences are fortunately the exception rather than the rule.

When the piece goes to the dyer and finisher, another, and still more costly defect may arise. Here I refer to listing, i.e., the piece shading gradually from

dark at the selvedge to light at the centre of the piece, or vice versa. A listed piece means 20 shaded coats. The shading is so very gradual that it frequently escapes detection. But when the coats are cut, the centre panel may come from the fold, and the side panels from the selvedge. Thus the two extremes are brought together, and the contrast in shade is most apparent. Since for the reasons given, the shading appears in separate panels rather than in one part of the coat, manufacturers jump to the conclusion that the pieces have been mixed, and one has to spend much time to provide definite proof. The best method of testing for listing is as follows :—

Take a strip of ¼ yd. across the piece, cut 4″ from each selvedge, and 6″ from the centre of the piece. Sew the selvedges to the centre, thus reproducing the contrast as in actual coat panels. In this way, any shade variation can be detected.

In worsted manufacture, the system is to send pieces to the dyer, for direct despatch to the customer. In most cases, the goods are not returned to the mill for re-examination, and the dyeing price includes the charge for perching, stringing, making-up, etc. For many reasons this is a bad system. Its only justification is the saving of labour and carriage. In actual practice, this is what happens :—The manufacturer must allow ¼ yd. for strings. He tells the dyer, in effect, " Too many strings, and I have my dyeing done elsewhere." The dyer is so diligent in his quest for " makers' faults " that he tends to ignore those for which he himself is liable.

Woollen Manufacture.

The woollen manufacturing industry is enjoying a period of prosperity which is well merited. Each year, designers become more clever, and finer ranges are produced. The mills are in a very strong position, since they are generally self-contained. If any difficulty does arise, it can be dealt with quickly. There are ny protracted negotiations between the representatives of four or five different parties, before a settlement can be arrranged, or a fault tracked down and corrected. In this connection, it is interesting to note that the larger unit, generally speaking, and allowing for one or two exceptions of note, attains a lesser degree of efficiency than the smaller unit. Most of the really successful mills have no more than 100 to 200 looms. Year after year, these mills find their cloths in great demand, and the season's production is frequently sold in a month. Since many mills specialise in tweeds or in piece-dyed cloths, it will be as well if we consider their productions under these heads.

Tweeds.

For the time being the plainer type of tweeds, such as velour-finished tweeds, have declined in popularity. There is a tremendous vogue for knop, gimp and boucle decoration. Therefore the mills who happen to have an adequate supply of twisting frames are finding themselves inundated with orders. Tweeds cause very little trouble, make up well, and give a very smart garment. The lack of defects is due, largely, to the nature of the cloth, which causes the majority of the faults to be covered up, yet in spite of this, the manufacturers are to be complimented on the high standard of their products.

Occasionally we find that a wrong cop has been inserted, giving a pronounced weft bar. In small or large check designs, the action of blocking the pieces may pull the check out of alignment, or, as we say make the check run off the grain. This gives a real problem, and it is practically impossible to produce a coat with the checks running horizontally.

When moss-finished, or velour tweeds are required, weft bars are very common. For this reason, such cloths are to be avoided whenever this is practicable. Take, for example, a two and two twill, with a brown warp and a natural weft. Uneven raising or cropping will show too much or too little of one or other of these colours. So far, I have not seen a piece that was finished satisfactorily in this respect.

This type of tweed is made largely from merino noil and it has a soft handle. On one occasion, a number of lengths were laid up for cutting, and the pattern marked in the usual way with chalk. This was done on a Saturday. On the Monday, the cutters returned, and found that during the weekend, the cloth had shrunk to such an extent that the garments would have been two sizes smaller.

Unless the oil applied to the wool to facilitate carding and spinning is completely removed, treatment with a hot iron will cause the oil to come through, and stain the rayon lining of the coat. This unusual fault came before my notice some time ago. It was found purely by accident, and the lining manufacturer had been unjustly blamed for the tweed manufacturer's mistake.

Piece-dyed Cloths.

Some mills are able to give a much better finish than others, and their cloths are always in great demand, particularly in the winter season. Frequently, work has to be given out to commission weavers, and there is often evidence of very great carelessness. If, however, the mills in question give out cloth to commission dyers and finishers in an attempt to keep pace with orders the result is impossible. It appears that the large commission dyer for example is unable to finish a fancy velour to compare favourably with the results which some of the small mills can obtain.

Delivery is always a serious problem, for the following reason :—Take for example, a mill with 100 looms, and an estimated production of say 250 pieces per week. Finishing capacity is 350 pieces per week. To work on mass production lines, the manufacturer decides to sell to a full production of 5,000 pieces per annum, or, let us say, 3,000 pieces for the winter season. The tendency will be to sell 4,000 pieces or more, to cover the possibility of cancellations, and in the hope of being able to get 1,000 pieces woven on commission, if need be. Thus, at the end of June, he probably has two months' production, or 800 pieces ready in the grey. Unfortunately, the merchants and makers-up cannot at that early stage, give a reliable lead on colours, and, as a result, the manufacturer is without colouring instructions. Instead of finishing his 350 pieces a week, he may only have finished 200 pieces in all the month of May. Therefore, at the very beginning of the season, he is already behind in finishing. This loss he is never able to catch up. During July and August, a rush in trade brings colouring instructions for literally hundreds of pieces. Dyeing time has to be extended from 10 to 14 days to a month, and he may be even a month overdue in delivery. The finishing department, therefore, is a bottle-neck, upon which annual success or failure largely rests.

If a manufacturer decides to sell to the limit of his weaving capacity then he must install sufficient finishing machinery to cope with four times his weaving output. The only possible alternative is to have a dyer and finisher who can put on a finish comparable to that on which the original cloth has been sold.

Late delivery upsets a maker-up even more than the merchant. Truly the latter loses in pocket, and (which is often more important) in reputation. The former suffers in both these respects, and in addition, his employees may be held up for work. The greatest sin in the making-up business is to have machinists idle during working hours, and then, when the cloth comes to hand, to have to pay overtime in order to catch up. Apart from this, coat orders may be cancelled, and the garments may be completely out of fashion a year hence.

As I have already pointed out, defects in dyeing and finishing are usually more serious than weaving faults in the case of piece-dyed velours. A badly set cropping knife can ruin a piece, by cutting too deeply, not deeply enough, or by cropping more from the centre of the piece than from the selvedge. In the last instance, the design will be clearly shown towards the selvedges, and obscure in the centre. Certain raised designs have a knack of catching in the blades of the cropping knife, or a knot in the warp may be cut. Subsequent friction

will cause the broken end or ends to come through, and by the time the piece has been delivered, what was originally a flaw too small to be perceptible, has probably extended to a hole the size of a sixpence.

As in the case of worsteds, the most costly form of imperfection is undoubtedly listing. This fault is even more prevalent in woollens than in worsteds, and is frequently augmented by the finish itself, and any slight variation therein. Once again, the " Strip method " of testing already described, is the best I have been able to find. Brown is the worst shade for listing, although it is to be found on all colours. Each season, some manufacturer gets a run of this complaint, while others are more fortunate. It has no relation to the type of raw material used, whether shoddy or carbonised noils. Whether it is caused by some imperfection or fugitive quality in the dye itself, by the percentage of alkali used, or by variation of the moisture content in the piece itself, I have not been able to determine, and I would be glad to know the explanation of this phenomenon. I cannot understand why one shade only should be affected when four or more shades are dyed from the same batch of grey, and under identical conditions. This problem is so serious that I wonder why we do not hear more about efforts being made to find a solution. Manufacturers have mentioned the lavish sums they would be prepared to pay if only the mystery could be solved. Has the Wool Industries Research Association reviewed the question at any time, and if not, will it be likely to do so in the near future ?

These, then are the chief faults to be met with as far as woollens are concerned. They occur year after year, with a monotonous regularity. Here too, the standard of passing is not nearly as rigid as it should be. Let it be clearly understood that a fault which has been strung is bad enough, but one that has not been so indicated means a damaged or imperfect garment. I do not think that I am exaggerating when I say that if coat passers were as lax in their supervision as is the average passer at the mill, the makers-up would very soon be out of business.

Rayon

Because of the comparatively recent origin of rayon, a greater tolerance of its defects exists. There are times, however, when this is carried too far. Rayon, after all, is " man made". Because of its synthetic origin, it ought to be more regular and more under the control of man than are the raw materials of animal, or even vegetable origin. Turning to the question of defects in rayon, let us first of all consider the flat cloths, such as viscose or acetate twills which are so largely used for coat linings. The best construction for a viscose twill is :—150 denier yarn, 80 ends × 64 picks, 2 × 1 twill, and with a press finish. It is of greatest importance that only first quality guaranteed yarns be used. There are, of course, many lower qualities on the market, but experience teaches that to go any lower than 80 × 52 is false economy, because weft slippage invariably occurs. The cloth will not wear well, and it will go under the arms, where there is the greatest frictional stress. The standard of weaving is exceptionally low, as I will show in these samples. Every piece has many damages, varying from ½ yard to 3 yards. Frequently, a poor warp is used, and the pieces are barred from beginning to end. I can safely say that in any piece of viscose twill, there will be a minimum of ten damages. Yet such pieces are sent in with from one to three strings. In the case of light-coloured goods, such as are required in the Spring season, there will be any number of black oil stains. Some time ago I had the privilege of going over one of the largest mills making this type of fabric. Everything was the last word in cleanliness and efficiency, and the research and testing laboratory set a standard that few mills could attain. In order to guard against oil stains as far as possible, the going parts of the looms were covered as best they could be. Even this precaution did not prevent the oil from being thrown up by the picking mechanism and from the

shafts. I discovered, however, that in the case of the more expensive crêpe cloths, a system of grading was employed. That is to say, the first grade, containing very few oil stains, was reserved for dyeing to very light shades, grade two, for medium colours, and the third grade, consisting of pieces which had been very badly stained, was used only for dyeing navy, brown or black.

I asked if this could be adopted in the case of viscose twills, as very little extra labour would be involved, and the benefit to the user was going to be very great. The system was immediately adopted, and has proved of great value to all the customers of this particular mill. This is, I think an example of the profitable results that can only be achieved when the manufacturer and the consumer can get together. I have always advocated a closer co-operation between the two parties, and I will continue to plead for this cause, at any and every opportunity.

Returning to the question of faults. The similarity in appearance of acetate and viscose yarn leads to instances of mixing, and I have here a fairly striking example of the result. Needless to say, this causes a considerable loss in material, and as the fault may come in the middle of a three-yard " lay", the actual loss is very much greater than the extent of the damage itself.

In rayon twills and taffetas, as in woollens and worsteds, listing is very prevalent. These cloths are usually made with a cotton selvedge, and the action of the rollers appears to force an excess of the liquor on to the lists, so that the shade is very much darker about one inch from the selvedges. A common fault is shading of the piece from end to end. Some pieces are a deep nigger at the commencement, and at the end of the piece the colour has changed to a very light brown. Occasionally we find a damaged roller imparting a repeating stain through the length of the piece.

One of the greatest disadvantages of twill linings is that since a press-finish is required, the tremendous hydraulic pressure to which the piece is subjected while in press-papers, imparts a fold mark every yard which no amount of subsequent treatment will eradicate. This gives an unpleasant appearance to the lining of the finished garment, and is one of the chief reasons for the present trend to discard twills in favour of taffetas for coat linings.

Most taffetas are acetate, and one would expect them to be much easier to weave. Also, I cherished the illusion that it would be easier to get accuracy of shade in dyeing. Unfortunately, the reverse has been the case, and both dyeing and weaving faults are so numerous that it may be necessary to revert to the viscose twills.

I have just referred to the problem of dyeing exactly to shade, and I would like to enlarge upon this because it is such a vital question as far as the maker-up is concerned. My remarks here apply equally to worsted, woollen and rayon piece-dyed fabrics.

At the beginning of the season, the maker-up who can buy the bulk of his cloth in the grey, adopts a standard range of shades. If he buys ten ranges, and colours up twenty pieces in each range, he must also dye 200 pieces of twill or taffeta, or perhaps some of each, to match these shades. He must also dye sewing cotton, perhaps in three or four counts, for different purposes. It is very essential that the cotton should match exactly, if trouble is to be avoided. A range of eight or ten buttons, in varying sizes, has been selected for the season, and each of these, probably from different manufacturers, has to be made in materials to match the shades of cloth selected.

When a manufacturer delivers pieces which are " off shade ", the whole system is thrown out of gear. The only alternative to returning the pieces, is to match up all these items specially, a very arduous task, involving considerable delay. Then again, it may well be that the shade delivered is not as suitable as the original colour, since standard colours are only arrived at after prolonged and serious consideration. In brief, the shade delivered is probably more difficult to sell.

SOME OBSERVATIONS ON RECENT PSYCHOLOGICAL EXPERIMENTS ON VISUAL AND TACTILE JUDGMENTS OF WOOL FIBRES.

BY PROFESSOR F. C. BARTLETT, F.R.S.

The published work of Mr. Henry Binns on the Judgment of Wool Textiles opens up, in my opinion, a wider field than he has himself contemplated. Practically ever since experimental method was introduced into pyschology, psychologists have been interested in tactual experiences and their investigation. But the bulk of the work has been devoted to a study of the specific responses to specific and usually experimentally isolated stimuli, and to an unravelling of the extremely complicated mechanism of touch response in and beneath the skin surface. There is therefore a considerable literature about varieties of temperature reaction, about touch spots, pain spots, absolute and relative thresholds and their mode of determination, and some, but much less, about the complication of tactual and visual experiences. Now and then people have written a good deal about the determination of thresholds by passive touch with cotton wool : much about this occurs in volumes like Sir Henry Head's collected works on neurology and in most of the psychology text-books.

But the work of Mr. Binns is different in general from all this. It raises a set of questions which I think to be of vital interest apart altogether from any question of replacing one technical method by another. He is not doing reaction tests limited to the response of one special set of sensory fibres to one special kind of cutaneous stimulus. He is conducting handle tests in which the external stimuli are provided by a mass of wool fibres, in the form of tops, having many different qualities all operative together, and in which probably a good many internal stimuli are provided by kinaesthetic and muscular sensations set up by movements of exploration. Quite a lot is known about the cutaneous reactions to each quality of " touch " taken by itself ; extremely little is known about the massed response of the cutaneous mechanism to the combined qualities when they are produced together. Yet if Mr. Binns is right one of the things that may result is the production of a finer basis of discrimination of differences. This has often been suspected. Suggestions along this line are to be found as far back as in Stout's Manual of Pyschology and probably earlier still, but I think it had never been demonstrated. Is this merely due to the fact that numerically more isolated data for discrimination are presented by wool fibres, or is it rather due to the fact that the combination of different cutaneous qualities gives rise to an experience peculiar to itself ? Is it due to the fact that active exploration gives a lower relative threshold of cutaneous discrimination—and that it does this is already well known—or is it that consistency of the direction of lie of the fibres, or regularity or irregularity of surface contour come in to direct the judgment ? Will a trained or particularly sensitive observer be able to isolate these factors or can it be shown that this is another case of his basing his judgment upon functional qualities of whose nature he is, and perhaps must remain, ignorant ?

It just happens that these, and similar problems, have, mainly by the influence of the Gestalt pyschologists, been made really live questions to-day and the technique of Mr. Binns raises them all. He claims to have found in standard wool tops a medium for the measurement of the sense of touch based on the definition of " softness "—a non-technical description capable of interpretation by almost all human beings. The word " handle " as it concerns textiles, he states includes about thirty descriptions of tactual sensitivity, most of them being of a technical nature : the same methods to define differences appear to be applicable to these as to " softness ", but obviously the judges must be experienced men.

The results of experiments carried out on a large number of individuals belonging to a diversity of different occupations, age and "interest" groups show, on wool tops, an astonishing agreement of grading as between visual and tactual methods. In only about 12 per cent. of the instances was there any significant difference in grading when visual judgments were compared with tactual and both were in close agreement with the standard arrangement of samples in the vast majority of cases. This may mean that the steps from sample to sample were definitely supraliminal for both vision and touch, but this does nothing to destroy the interest and importance of the agreement. For the sensory patterns underlying each type of judgment must been have markedly different. The criterion for visual gradings was "fineness" ; for touch it was "softness". It seems highly desirable that a thorough investigation should be planned into the efficiency, limits, range and precise breaking down points of "matching" where reactions having different sensory or general experiential bases are concerned. And it seems to me that both the materials and the methods of Mr. Binns' investigation could be made a good starting point for such an enquiry. The evidence he presents so far seems to indicate that visual judgment is the more technical and trained ; the tactual, or handle judgment is the more native and immediate. Marked individual preferences may exist for one or the other of these two types of judgment, and that corresponding to these there may be variations of efficiency.

The general trend of science is to reduce or eliminate errors of judgment. In problems in which the factors are numerous, complex, irregular and fluctuating (e.g. in the wool trade) reduction of errors usually follows experience and systematic training; their elimination is impossible. Hence from another angle Mr. Binns has analysed and tabulated a formula of "Fundamentals of Sound Judgment", which as a business man and a textile technologist he has carefully tested and then corrected by observation. In this direction there would appear to be much in common with pyschologists who need data on which to base new principles.

With all this pioneer work I am in hearty agreement and trust that it may be followed up by others.

Reviews

Mathematics for Technical Students (with Answers). By F. G. W. Brown. Published by Macmillan & Co. Ltd. London. (478 pp. Part I, 3/-. Part II, 3/6.)

The two parts of this book "cover completely the First and Second Years' courses in Practical Mathematics laid down by the Union of Lancashire and Cheshire Institutes for the Preparatory Senior Technical Courses, while the whole book covers the First Year's Syllabus in Mathematics for the Senior Course in Mechanical Engineering, Electrical Engineering and Naval Architecture, as well as the Third Year's Course in Electrical Installation of the same authority". The object of the work is to provide a more logical treatment than those which appeared in earlier books on Practical Mathematics which "often consisted of little more than an enunciation of a number of pocket-book rules".

In the elementary arithmetic an outstanding feature is the clear explanation of the meaning of significant figures. The almost imperceptible introduction to algebra by means of symbolic representation should not prove difficult to any student. To carry geometry from the definition of an angle to the cyclic quadrilateral in a chapter of about 35 pages, one would have thought impossible, but it is done.

The treatment of logarithms, as an application of the laws of indices is well done and no difficulty should be met with the negative characteristics. Greater stress might have been laid on the fact that tables of antilogarithms though very convenient are not essential as many students imagine.

In so far as it is possible to get away from the style of the early books on "Practical Mathematics" and from asking the student to accept formulæ

without proof, this has been done. Many examples and examination papers are provided and these volumes should therefore be of great value both to students and teachers. T.

"Nihil Novum Sub Sole!" By P. Rodon y Amigo. Monografias Tecnico-textiles, Cataluna Textil, Badalona, 1937. (244 pages. 15 pesetas).

The problem of weaving on a dobby loom cloths with extended repeats in the direction of the weft has always been a fascinating one for designers. Of the various devices which may be employed to facilitate the evolution of such a pattern none can equal, either in scope or ingenuity, the system devised by Delamare-Deboutteville (B.P.358,467). Probably because of the comprehensiveness of the system, on account of which many designs which it gives can also be claimed as examples of other well-known artifices, it seems to be particularly liable to attack from those who think that it lacks any element of novelty. Among these is Sr. Amigo, and in this volume he sets out his case at length, taking as a basis for criticism the Spanish patent of the inventor (this, incidentally, differs entirely in presentation from the British one, and, we think, lacks the clarity of it).

A fundamental step in the Delamare system is to analyse a design not into the usual draft and pegging plan, but into two drafts, one for warp (identical with the usual one) and one for weft. Sr. Amigo points out that the idea of synthesizing a pattern by means of warp and weft drafts coupled by a basic weave—using this in a rather different sense from the usual one—is by no means new; but far outstripping this in importance in the Delamare system is the fact that each draft may contain many more lines than there are shafts available. Is not this really the crux of the matter? Sr. Amigo deals with the "weft-draft" idea in considerable detail, giving many examples of designs evolved by its aid, and he also considers the coupling of two perpendicular "drafts" of continuous or discontinuous zig-zag lines to give a figure in outline, a process which seems to us particularly noteworthy. The somewhat quaint notion of representing the letters of the alphabet by suitable signs, so that each draft can be made to stand for a word or words, and thus obtaining a figure which is a cipher of the words of the drafts, is a further development which might have an appeal for some. Other chapters deal with tesselated designs based on diagonally divided squares, and the amalgamation of weaves, but the greater part of the book is devoted to criticism of the Delamare system. With regard to this one cannot help asking whether the author has not fallen into the error mentioned above, and it would be interesting to have his reaction to the design given in the British patent.

On the whole, the book should be of great interest to designers, and the 180 excellent illustrations should be informative even to those unfamiliar with Spanish. The print and binding are good, but we should have liked to have seen the corrections given in the list of errata incorporated in the text. H.J.W.

The Science of Pattern Construction for Garment Makers. By B. W. Poole. Published by Sir Isaac Pitman & Sons, Ltd. (520 pages. 45/- net.)

The latest edition of this comprehensive treatise has been thoroughly revised and enlarged. The general treatment of the subject is good and although many books have been published on garment cutting this must surely be the most exhaustive volume which has ever been put before the trade. It covers every garment a cutter can be expected to encounter in normal circumstances, examines every phase of cutting and gets down to the very root of the matter from the first pages.

The compilation of such a work demands from its author a deep and thorough knowledge of his subject; that this is particularly the case so far as Mr. Poole is concerned is borne out not only by the 500 pages of interesting and instructive matter but also by the fact that the author tells us in a foreword that he is not attempting to give us a fashion guide but rather to provide a basis on which the reader may plan any fashions he requires. The book, therefore, is not so much a thing of the moment, to be treated as a style plate, but a volume of reference, and indeed, a veritable encyclopedia. It is a book on which the student will find his money well spent and it will provide him with an ever ready assistant enabling him to meet most problems which may confront him in the future.

As to the book itself, it has certainly been written with the idea of educating the student who will have to put his knowledge to practical use and earn his livelihood by cutting. In order to do this in the most attractive manner Mr. Poole has obviously tried to place himself all the time in the position of the untrained student and explains in simple language the many difficulties connected with the trade. He deals extensively with every phase and snip of the shears and treats on a sound and solid basis the design of almost every conceivable garment.

The experienced cutter will probably say to himself that there is really nothing new in the book but the explanations are so clear cut and the scope of the volume so vast that there can scarcely be a cutter engaged in the trade who would fail to find the book useful at some time or another in the course of his career. The tuition does not stop merely at wordy explanations, for the volume has been profusely illustrated with a series of excellent plates and carefully thought out charts and illustrations. Mr. Poole has been fortunate in securing the assistance in this connection of artists from the Leeds School of Art and he has been helped in no small way by the excellent productions of his assistants. It is interesting to note that Mr. Poole tackles fearlessly quite a number of subjects which have always created controversy throughout the trade and not only does he give a direct lead but also gives his reasons for that lead.

In the first twenty pages we are taken carefully through form growth and anatomy to the construction of coat patterns, and later in the book a complete chapter is devoted to the study of corpulency and provisions for dealing with figures of this nature. Later on the subject of boys and juveniles comes in for much consideration and full prominence is given to specialised garments such as hunting coats, military tunics, morning coats, frock coats and other garments calling for skill and study. The author deals with the vexed question of measuring very fully, and whilst some experienced cutters may not agree with Mr. Poole's system and with his claims for that particular method few will disagree that for the beginner his system is sound.

The effect of materials upon good contruction is effectively dealt with in a separate chapter and we are afterwards given excellent guides in following pages on overwear, collar constructions, vests, trousers and breeches and other particular garments in general use to-day.

In spite of its title, the book is not devoted entirely, as might be expected, to pattern contruction and many pages are given up to the study of alterations and the reasons why a garment looks ugly on the wearer and is not the success its designer intended that it should be. This section is illustrated with actual photographs and the whole subject is very extensively surveyed. In this chapter alone the student will find full value in return for his studies.

Mr. Poole, although confining the main portion of his book to the men's section, allots nearly 200 pages to the problem of the women's garments and as a basis for tailor mades his treatise will be found to be a sound one and it should be possible for his reader to cut almost any garment from his excellent descriptions.

The book raises the subject of several interesting discussions, many of which are debatable but the reader must remember that the volume has been written from the teacher's point of view and particular application of the knowledge which is to be gleaned from its pages will not only broaden the mind but will materially assist any student ready to take advantage of the author's vast knowledge.

The book can be strongly recommended to the student, the experienced cutter, and also to everybody requiring permanent reference on all subjects connected with garment cutting and construction. Mr. Poole is to be congratulated on the compilation of what is without doubt an outstanding addition to the tailoring trade. I.S.

Flexible Budgeting and Control. By D. J. Garden, M.A., B.Com., Ph.D. Published by Macdonald & Evans. (xii + 244 pages. 7/6 net.)

Business men of wide outlook will welcome this recent addition to publications seeking to improve business efficiency. The author is a Lecturer in Industrial Administration at the College of Technology, University of Manchester. It is right and proper that members of university teaching staffs should take every opportunity to publish their recommendations, in order to establish themselves

in the confidence of contributors to university funds. When the subject matter of the publication is of the satisfactory character and paramount importance of Dr. Garden's latest work, it is gratifying to realise that the training of our future administrators is in such capable hands.

The reviewer welcomes the term " Flexible Budgeting " as there is no doubt that no rigid system can be applied to the majority of commercial enterprises with the same exactitude as to that with which our Chancellor of the Exchequer deals. He is able to budget because he is furnished with estimates of income and expenditure of a more or less compulsory and definite character. A careful reading of Chapter I in the work under review will, however, satisfy the most incredulous that a budget based upon correct statistical records is absolutely essential to effective costing and control.

As a practical illustration the first example given by Dr. Garden on page 9, may be reproduced.

Table showing the changed Incidence of Overhead Charges :—

OPERATION " A " (Turning and Boring).

	Pre-war costs.	1930 costs.
Labour	62·42%	20·48%
Overhead charges	37·58%	79·52%
Total	100·00%	100·00%

OPERATION " B " (Gear-cutting).

	Pre-war costs.	1930 costs.
Labour	61·40%	29·20%
Overhead charges	38·60%	70·80%
Total	100·00%	100·00%

Of course it scarcely need be pointed out that the changes both in overheads and wage rates are constantly being affected by the introduction of automatic labour-saving appliances, which it is generally conceded should be allowed to benefit both employee and employer.

The changing incidence of costs, as affected by the variation of different degrees of activity and turnover, are clearly indicated in Tables II and III. Further tables effectively illustrate the detailed headings under which statistics should be available and Dr. Garden makes these applicable to manufacturing industries, retail stores, the making-up and sale of ready made garments, or any other specialised form of business enterprise.

The statement attributed to H. Gordon Selfridge that the modern department store carries 12,000 different kinds of gloves, 5,000 varieties of handkerchiefs, and 4,000 makes of handbags, besides a constantly increasing variety of articles of all kinds will, no doubt, persuade the least methodical person that sales records have to be studied before further purchases can be wisely made.

Dr. Garden, however, very soundly illustrates the fact that mere statistical records do not of themselves save the situation, but must be accompanied by a form of flexible planning and budgetary control which allows ample room for the exercise of wide comprehensive judgment of the probable trend of market influences. These influences may be due to political, national, or international actions, instability caused thereby or even the fickleness of fashion. A budget may have to be scrapped or modified in the light of current happenings. It is difficult to imagine that there is now any industry in which records of the quantity and cost of stores and renewals in ratio to output and value are not kept. These particulars have proved useful and should be continued as a valuable guide to heads of departments with regard to proved values. Together with all other important factors such as output and eficiency, they must be co-ordinated and given due consideration in relation to the larger questions affecting budgetary control, which a capable managing director should take into his purview when directing future policy. As Dr. Garden states the successful operation of a business budget may depend upon an adherence to those ten well-established principles of organisation and important rules of management

which Mr. Rorty put forward at the meeting of the American Management Convention a few years ago.

These are detailed on pages 22 and 23 and are well worth the attention of any person acting in a managerial capacity. The sub-headings suggested for an Overheads Journal in Fig. IV, page 30, are very helpful, but of course must be supplemented by other journal sheets recording facts relating to raw and worked materials, percentage of waste material, labour charges and other variable overheads in each department, including purchasing and sales.

The last named are effectively dealt with in Chapters II and III under the headings of Salesmen's Surveys and Estimates, Analyses of Past Sales and Potential Demand, Psychological influences, Methods of Advertising, General Trade Conditions, Trade Cycles and Statistics, Price-fixing Considerations, the wisdom or otherwise of price-concessions. Dr. Garden very properly differentiates between budgeting for standard products and for special orders requiring prompt delivery, and points out that the works manager must furnish frequent reports regarding output and progress in order to avoid late delivery. In the case of texile mills detailed information respecting any limited output of combers, doublers, warpers, or width and equipment of looms must be recorded with instructions to the salesmen to secure the type of orders best suited to the machinery available, until such times as it is found profitable to modify the equipment.

The capital expenditure budget and control of finance are effectively dealt with in pages 125-155 and Dr. Garden wisely points out that the investment of capital in fixed assets is a phase of business activity in which a mistake is difficult to rectify. The remarks that to-day's tendency towards the replacement of men by machines and the low degree of adaptability of modern labour-saving machines to purposes other than those for which originally designed, attach an added significance to a firm's investment in plant and machinery. Of course the amount of this risk varies greatly in different industries.

The reviewer greatly commends Dr. Garden's statements suggesting Budgeting for a Pre-Determined Minimum Net Profit and considers the suggested Preliminary Statement of Profit and Loss as set forth in Fig XX to be worthy of careful study. The remarks on Balance Sheet Criteria and the demand in many businesses for a degree of liquidity of resources greater than the ratio of liquid to total assets essential in others, is also of great importance. The valuable book under review closes with pertinent remarks regarding Retail Budgeting, Sales Quotas, Sales Areas, Special Order Firms, Fashion and Style Factors and Seasonal Factors which further intensify the fact that it should not only find a place in the library of every business man, but should be read by every departmental head, company secretary or accountant.

In the United States accountants take up studies in specific branches of industry where their fundamental knowledge proves of value to clients. This specialisation would certainly help accountants to select and advise which of Dr. Garden's suggested tables could be adopted with the greatest benefit to any particular type of business.

J.C.

The Application of Statistical Methods to Industrial Standardisation and Quality Control. By E. S. Pearson, D.Sc. (Published by the British Standards Institution, 161 pp. Price, 5/-).

As the title clearly indicates this book is concerned with the application of statistical methods rather than the mathematical theory underlying them. Some of the simpler quantities are dealt with very briefly in appendices, but the book keeps closely to its set purpose of discussing the application of statistical criteria to Industrial Standardisation and Quality Control.

The work though primarily due to Dr. E. S. Pearson, arises from the deliberations of a committee of the British Standards Institution which met with the object of reporting on the application and use of statistical methods in standardisation and specification of quality, and awakening interest on the part of manufacturers and others in connection with the problems concerned in standardisation.

The question that must constantly appear before the investigator dealing with an inherently variable product is "Have I got a truly representative sample?" Statistical methods of analysis are applied to measurements on

samples in order to extract from them data of known reliability relating to the whole of the production. Those whose mathematical equipment is slight will be encouraged by the treatment of the subject in this work. So long as the only available treatments were the highly mathematical ones, the application of statistical methods inevitably remained in the hands of mathematicians.

Conformity to a specification may be secured either by testing samples from consignments or by requiring that "records be kept by the producer which, supplemented by a system of check testing, will provide statistical evidence of the level of control during manufacture." Some of the advantages of the latter method are so obvious that it is hardly necessary to draw attention to them. It is good to see stressed the importance of preliminary investigations on statistical lines before the conditions for sampling and testing can be properly laid down.

The readier treatment of observations when the distribution conforms to the Gaussian or Normal Curve is noted. The following quotation will re-assure the reader of limited mathematical attainment and should convince him that statistical work is not solely the province of the mathematically minded. "It would seem well to take this opportunity to discourage a popular belief. There is no magic about the Normal Curve in the sense that if a distribution follows this law, that is proof that the variation of the product is stable and under control. Nor is it only possible to use statistical methods when the variation is normal."

Putting as it does the application of statistical methods in the hands of those whose mathematical training ended with simple arithmetic, this book cannot be too highly recommended to all concerned with the testing of materials and their production to controlling specifications. T.

The National Physical Laboratory. Report for the Year 1936. H.M. Stationery Office. (144 pages. 2/6 net.)

This report makes very interesting reading indeed. It should convert, if there are any left, all holders of the old opinion that scientific research is not practical. The increase in a ship's efficiency by more than 10 per cent. as a result of experiments at the laboratory is not to be regarded as a justification of research work but rather as a proof that no ship should be built until the experimental tank tests have been carried out. Textiles do not form part of the normal activities of the Laboratory. If textile testing or research is undertaken it is usually in connection with Government specifications or where it is subsidiary but necessary to some main problem more strictly physical. An example is provided in the case of the report on dry cleaning reagents. It is difficult to imagine that the work could have been done more capably in any other establishment. The effect of the addition of suitable soaps in increasing the electrical conductivities of these dry cleaning liquids and so reducing the tendency towards the generation of electric sparks by friction is a valuable step towards minimising the risks of explosion inseparable from the use of such reagents as benzine or petrol.

The National Physical Laboratory's versatility could hardly be better illustrated than by contrasting such work as the protection of metals against corrosion or the development of a new series of light alloys for aircraft purposes with that on the vibration clock or the latest test of the general theory of relativity. For the full appreciation of the work at one end of the Scale the training and outlook of the physicist may be necessary. But the practical importance and the application to industry of the greater part of the work will be at once obvious and of the greatest interest to all concerned.

T.

Additions to the Library

In addition to the list supplied in the March Issue of the *Journal*, the following firms have now supplied catalogues :—

Crompton & Knowles.—Looms for silks, cottons and rayons.

Imperial Chemical Industries Ltd.—"Taninol W.R.". A "Wool resist" for preventing the staining of wool in the burl dyeing of wool-cotton unions with direct cotton dyestuffs.

Newton & Co.—Projection Microscope. "Ampro" 16 m.m. motion picture equipment.

THE JOURNAL OF THE
TEXTILE INSTITUTE

Vol. XXVIII MAY 1937 No. 5

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

SOUTHPORT CONFERENCE—June 9th, 10th and 11th

A Final announcement has been sent to all members and a Form of Attendance is inserted also in this issue. Although at the time of writing this note the record of attendance is up to the usual numbers, there is ample room at the headquarters hotel—The Prince of Wales—for twice the number registered. The two introductory papers to the discussion sessions of Thursday and Friday are in print and copies can be sent to those who contemplate attendance and will take part in the discussion. The success of the event depends in large measure upon the extent to which members take part in the discussions, and the introductory contributions by Mr. C. M. Whittaker and Dr. F. T. Peirce have been printed in advance to facilitate the fullest possible debate on the whole subject of the Serviceability of Fabrics.

The Chairman for the first discussion session on Thursday (the 10th) will be Mr. F. Schofield, and invitation has been extended to Sir Robert Pickard to preside on Friday, 11th June. Members in attendance will welcome the opportunity to show their appreciation of the honour recently conferred upon him and it is hoped his engagements will permit him to be present. Principal B. Mouat-Jones will take the chair for the Mather Lecture by Sir Harold Hartley, and the Institute President, Mr. John Crompton, will preside at the Banquet.

No further general communications will be made in connection with this event, but a further dispatch of literature to those who have sent in Forms of Attendance will be made in the first week in June.

Obituary: Miss E. R. Dust and Mr. Frank J. Farrell

The Institute has lost during the month two valued members. Miss Emily R. Dust, Lecturer in Textile Design in the University and Technical College of Manchester, though only recently added to the Members' List of the Institute, had done much to help in the work of the Competitions and later in connection with the Reference Collection of Fabrics in particular. In this work she was associated with Mr. Essan, also of the College of Technology. At the prize distributions, Miss Dust readily gave help in arranging the display of competitors' albums and fabric lengths and the exhibitions thus staged owe much to her enthusiasm and good taste. Her many friends will feel this loss keenly.

Mr. Frank J. Farrell, for many years President of the Silk Association of Great Britain and Ireland, had been a member of the Institute since its early days. His sudden death came as a shock to his many friends and acquaintances, and his services to the Silk Industry will be much missed.

TEXTILE INSTITUTE DIPLOMAS

Election to Associateship has been completed as follows since the appearance of the previous list (April issue of this *Journal*) :—

ASSOCIATESHIP

MARSDEN, Hermon (Manchester).

Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application :—

No. 158—A.T.I. requires position as Spinning Master or Inside Manager. Experience in all qualities, Twist, Weft and Hosiery Yarns, Cotton, Wool and Artificial Silk Mixtures. Prepared to go abroad. A.M.C.T. Age 30 years.

No. 159—Requires position as Wool Buyer, preferably in carpet trade, or Assistant Mill Manager. City & Guilds Full Technological Certificate in Woollen and Worsted Yarn Manufacture. Prepared to go abroad. Five years' experience in sorting all classes of wool. Age 27 years. A.T.I.

No. 160—Applicant, age 26 years, desires position as Salesman or Assistant to Director with fine Worsted Spinners. Prepared to go abroad. City & Guilds Full Technological Certificate. Knowledge of French and German. Nine years' experience with Bradford Firm of Worsted Spinners.

No. 161—Desires position as Manager or Assistant Manager. 23 years' experience in furnishing fabrics. Conversant with all processes. Evening School lecturer in Textile Weaving and Designing. City & Guilds Certs. in Woollen and Worsted Weaving and Designing. A.T.I. Age 40 years.

No. 162—Young man, 27 years of age, desires position as Manager of Worsted Manufacturing concern. City & Guilds Cert. in Woollen and Worsted Weaving. Four years' part-time lecturer on Weaving Mechanisms. Willing to go abroad. A.T.I.

Institute Membership.

At the *May* meeting of Council, the following were elected to Membership of the Institute :—

Ordinary

Baguley, N. G., Jubilee House, 207-213 Oxford Street, London, W.1 (Director of Retail Trading-Standards Association Testing House).

Banerji, N., Government Central Weaving Institute, Amritsar, Punjab, India (Textile Master).

Duckworth, H., B.Sc.Tech. (Manc.), 107 Napier Street, Nelson, Lancs. (Piece Goods Salesman, Thomas Moss & Sons, Ltd., Manchester).

Gerrett, W. R., c/o Henderson, 23 Royal Terrace, Glasgow Road, Paisley (Foreman Dyer).

Hanson, D., B.Sc., A.I.C., 42 Savile Drive, Savile Park Road, Halifax (Works Chemist, John Crowther & Sons (Milnsbridge) Ltd., Huddersfield).

Macpherson, R. G., Summerhill, 14 West Cliffe Mount, Harrogate (Insurance Broker and Inventor).

Vashist, S. D., M.Sc.Tech., Vashist Ashram, Abbott Road, Lucknow, India (Textile Examiner, Indian Stores Dept.).

Junior

Binns, J. S., Laurel Grove, Keighley (Manufacturer, J. H. Binns & Co. Ltd., Keighley).

Shaw, A., c/o N. Howard, 33 Holly Street, Tottington, nr. Bury (Assistant Works Chemist, Kirklees Ltd., Tottington).

Thornton, W., 9 Thomas Street, Rastrick, Brighouse, Yorks. (Assistant Manager, Baldwin Armitage Ltd.).

London Section

CO-OPERATION BETWEEN MAKER-UP AND MANUFACTURER

By G. Haigh, F.T.I.

*A paper given to the London Section of the Textile Institute, on April 28th, 1937, at the Hotel Victoria, London. Being a reply to the paper " Textile Defects and other problems which confront the Making-up Trade," by G. N. Warnock, Esq., on the 5th February, 1937.**

Mr. Haigh opened with a few comments on Mr. Warnock's paper. Mr. Warnock, he said, had delivered some telling blows and the points in question were so important that they could not be allowed to stand unchallenged. In his reply he might have to hit hard both on his own behalf and on that of his friends in other branches of the cloth trade. But he hoped that everyone would agree that his defence had been as sporting as Mr. Warnock's provocative yet good-natured attack. Mr. Haigh said :—

" Of the definite points raised by Mr. Warnock the first one is in the distinction between the requirements of the merchant and the maker-up, where it is pointed out that the merchant may require a cheaper cloth than the maker-up in order to be able to sell at the same price as the manufacturer. One has no doubt that this position obtains in many cases but in connection with this view I would make these observations. It would appear from such a position that the maker-up was incapable of judging the difference between the value of the two cloths and from experience I should say that this is far from being the case. It is a fact, however, that many makers-up rely on the manufacturer to advise them on cloths and guide to some extent their purchases.

" Then again, certain makers-up having bought a cloth to run for the season very often ask the manufacturer, ' To which merchants have you sold this cloth ? ' the reason for the question, being definitely, that the maker-up requires to know where he can obtain supplies of this particular fabric when the rush period is upon him, and he is quite prepared at such a time to pay the extra price required by the merchant. This to my mind is good distribution ; allows for the rush period and gives the merchant a chance to do at any rate a certain amount of business with the larger makers-up, and does not leave him merely the small makers-up and retail trade as his sole outlet.

" It is quite true that usually the London merchant has no means of examination : he still, however, remains liable to his customer and though legally the manufacturer's liability ceases when once the goods have been passed by the merchant, in actual fact this is usually not so. I am in entire disagreement that a low standard does prevail as neither merchant nor manufacturer could exist for very long were this so. I would submit rather that the merchant's confidence in the manufacturer has been built up by long experience.

" Incidentally I would point out that Bradford merchants have the fullest facilities for examination and do not fail to use these means to the utmost. A system has sprung up during the past few years whereby the maker-up and packer supplies the merchant with offices, storerooms, etc. usually on condition that he does the perching, making-up and packing for the merchant. The training of these perchers began some ninety years ago when a number of German merchants came to Bradford and took charge of the distribution of the city's products. They were hard task-masters and every Bradford manufacturer knows the meaning of the term ' Top Room ' where pieces are usually perched in

* This *Journal* April, 1937; pages P85—P93.

a cold North light. The many steps are well worn and it is interesting to note that the downtreads are even more worn than the upward ones, but these German merchants raised the standard of production up to the high level that still prevails, in fact, there has been a steady improvement since the War period. Moreover, the British standard is higher than that of any other country. This question of standard and perching occurs two or three times. I will refer to it again in order to keep the same sequence.

Survey of the growth of the Making-up Trade

" The story of the evolution of the making-up trade is an interesting and important one for it allows the manufacturer to appreciate more fully the changes that he himself must make in order to meet the changing conditions of his customer, and one appreciates that there is less opportunity of dealing with small faults under modern conditions than was the case when the garments were made individually and the ' cutter,' by a slight adjustment, was able to avoid a fault.

" It might well be noted that in the men's wear trade a practice has recently come into use of cutting up the cloth at full width with approximately a five yard lay-out which means that one part of the garment is no less than ten yards of cloth distant from another part and these two portions may come together in the garment. This, of course, calls for extraordinary precaution in seeing that there is not the slightest difference in shade from one end of the piece to the other.

" Under this heading comes the question of '*costing*'. Unquestionably if the maker-up orders 54 inches he has a right to expect 54 inches. In our own mill the practice is carefully to measure the width of the patterns in the loom, in the grey, and in the dyed states and then allow from half to one inch margin for variation by the finisher. It is true that occasional pieces turn out to be narrow, which usually happens where pieces have been turned down by dyer or manufacturer, either for shade or stains, etc., and re-processed. The proportion, however, that use up the margin allowed is small and even in those cases usually the customer is agreeable to accept the piece at a reasonable allowance.

" When pieces are found to be narrow by the merchant or maker-up it is not always the case that the manufacturer has sent his pieces out narrow deliberately. Too tight rolling and ' creeping ' can affect the width after having left the delivery room. To look at the point from the lowest attitude, width is so easily checked that a manufacturer is foolish not to point out narrow width to his customer and to come to some arrangement with him.

"It is fully agreed that every piece should be examined for the points enumerated, namely : weight, width, strength, shade, freedom from listing, freedom from ending, finish, correct yardage and of course the faults strung. It is obviously agreed that if the cloth is sold 16 ozs. the deliveries also should weigh 16 ozs. at correct condition or within reasonable limits. No reliable manufacturer for his credit's sake would attempt to deliver an oz. per yard light. Some allowance is necessary both above and below the stated weight as many estimations have to be made in producing a cloth, such as length and width outcome, loss in weight from oil, natural grease, and fibre, which are not always the same under piece dyeing conditions as in the original pattern dyed in a short length.

" Certainly the description ' All Wool ' does not mean 15 per cent. cotton but as a worsted yarn containing 15 per cent. scribbled cotton costs more than an all wool yarn and is used solely for effect the probabilities are that such a description was given inadvertently. No manufacturer in his senses would deliver 15 per cent. cotton for ' All Wool '.

" The strength test is particularly important in woollens, and exceptionally so in cloths of the velour and duvetine character, as the cloth is undoubtedly weakened by continual raising and cropping.

"It is agreed that the maker-up puts considerable trust in the integrity of the manufacturer, as it is inconvenient and expensive to re-perch and re-measure the whole of his pieces, and whilst the weight is a rough test of the accuracy of the delivery so far as the length is concerned I would suggest that occasional pieces are checked over the five yards table.

"Then we come to the question of what Mr. Warnock calls 'The platitude about the perfect piece'. I would point out that within a few sentences he himself says that the buyer must expect a certain amount of imperfection. Obviously these two phrases are contradictory, the so-called platitude means what it says—perfect, i.e., without blemish, evidently Mr. Warnock takes the Oxford Dictionary meaning of the word 'perfect'—(*loosely* used) 'comparative excellence'.

"Remember that in the finished piece you have all the faults which human beings are liable to throughout all the processes of combing, spinning, weaving and dyeing.

"From a long experience of dealing with the making-up end of the industry I am glad to say that the standard demanded by them is reasonable and all they ask is that faults must not show in the made-up garment, and generally speaking, no manufacturer would object to this standard. It must not, however, be forgotten that the same standard cannot be expected in a cloth costing 6d. per yard as in one costing 15/- per yard. That presumably is axiomatic.

"It has been said that the customer gets what he pays for. To illustrate this may I give two examples. First, where the manufacturer is ground down in price to cost or below, the temptation is, to buy the yarn from the lowest price spinner regardless of the quality of the workmanship and to send the pieces to the cheapest dyer. He may be blamed for this, but he is no more blameworthy than the merchant or maker-up who come to that manufacturer because he was the lowest priced man on the market on that particular day, regardless of any other consideration. Second, customers have paid as much as 2/6 per yard extra to obtain the highest standard that can be given and this extra price was used by employing improved wool quality, knotless yarn, slub trapping, etc.

"The human element does not mean 'carelessness or neglect'. It means the workpeople are not perfect machines ; nor are the merchants or the makers-up. To say 90 per cent. of faults are due to carelessness or neglect is sheer folly and ignores the many difficulties which appertain to the production of cloth.

"The maker-up often ignores strings and then brings the manufacturer to book for faults which have been strung. A manufacturer who visited a large firm of makers-up when a workman who was laying out the cloth ready for cutting up was asked what the strings were, and the workman replied. 'They are used by the manufacturer in measuring the piece.'

Worsteds

"The ladies' trade in worsteds has not been to the fore, but thanks to many foreign markets who have a greater appreciation of the value of worsteds, manufacturers have been and are to-day busy in spite of the fact that some users in this country have 'pooh-poohed' worsteds. This season a merchant traveller was turned down and severely criticised because he had no worsteds to offer when showing to a maker-up who told him it was worsteds he wanted.

"Certainly prices have advanced with startling rapidity and ideas of cloth basis and prices have to be entirely altered, but from various sources one has the whisper that worsteds are 'coming again' into their own.

"Mr. Warnock mentioned sympathy for the manufacturer who is so much in the hands of the wool man. It should, however, be remembered that the wool man cannot control the price of wool. The English wool-buyer can effect the price in a small way, but the real control is world-wide and no single country even can control it.

"I regret to hear that Mr. Warnock feels so little pleasure in selling worsted, as compared with woollens. Surely there is always some satisfaction in selling a good article. He also mentioned the 'Back room office manufacturer' and legislation to prohibit this type of trading. This is a free country, however, and such a procedure is very unlikely. Buyers can, however, overcome the difficulty by not buying from such firms.

"The use of stop-motions is mentioned in order to prevent ends down extending from a quarter to one-and-a-half yards. Up to a point, yes! The use of stop-motions can be of great help in difficult weaving; it should, however, be remembered that the droppers of the warp stop-motion themselves have a detrimental effect on weaving and this motion can only be used where the price of the cloth warrants a quality of warp that will withstand the extra strain put upon it. The motion is particularly useful in warps containing a small number of ends. You will, of course, realise that where there are a very large number of ends, such as 15,000, the cost of inserting this large number of droppers is not negligible, particularly if it is only for an odd warp. The use of the motion is undoubtedly increasing.

"The statement is made that weft bars are common. Weft bars certainly do occur but I don't agree that they are common, and am astonished to find the statement made that there are far too many oil stains. Bradford sells thousands and thousands of creams and light shades every year and the statement that oil stains are frequent is astounding in view of the fact that the bulk of the making-up trade shade requirements are navy, black and nigger.

"Bradford works to a maximum of six strings in a piece which covers faults made by all processes.

Listing in Worsteds

"Listing does occur occasionally, but too much is made of this point. In my own personal experience only two cases of serious listing have occurred in well over thirty years. Three individual piece dyers quote their return of pieces for mending for this fault as under ½ per cent. From one cause browns do certainly seem to have a peculiarity of showing listing caused by the 'condition' in the piece being driven to the edges in pressing. The manufacturer should watch this in the perching operation and return the piece for mending. Listing can also be caused by faulty crabbing and scouring where impurities in the piece which are driven to the edges have not been properly cleared before dyeing, causing the edges to resist the dye.

"The method suggested of testing for listing by cutting swatches from the piece, edges, etc. is rather drastic, as a full test can only be made by drawing samples throughout the length of the piece. The method usually employed is to bring the edges and centre together on the perpendicular perch at various points during the operation of examination.

"The system of perching by the dyer needs very little comment because surely no manufacturer of standing will leave the dyer to perch worsteds. In my experience the system is most prevalent where the manufacturer sells his cloth in the grey state, the dyeing being in the hands of his customer. There is, however, no need for the customer to employ this method as he can have his pieces efficiently perched by a professional maker-up and percher in Bradford.

"Mr. Warnock considers that the standard of production in worsteds is low; I don't agree. Yorkshire worsteds still have an exceedingly high reputation throughout the whole world to such an extent that the pieces can be delivered to countries having a 100 or more per cent. duty against them, and it will be readily understood that pieces going to such markets must be of high standard.

"Occasionally parts of a garment are returned after making-up and even then one sometimes has the suspicion that the fault has been strung and no notice taken of the string in making-up.

Woollens

" Mr. Warnock's prejudice against worsteds is only too clearly shown by his drastic criticism of worsteds and their producers and the smooth gliding over of all troubles in woollens. Any buyer or user of woollens will tell you of the many troubles of the woollen trade; variation of weight, condition, lack of cover, barriness. These features are inherent in the low quality of the materials used. The woollen manufacturer does not merit his prosperity simply because his article is popular. The worsted manufacturer also makes huge ranges of styles. A large West End firm told us last season ' I can get any novelty I require in Bradford and I have no need to go abroad. My only difficulty is to pick out the winners from the large ranges I see."

Tweeds

" The only point raised here is the question of drawn checks. The same point is raised under the heading rayon dress cloths. The fault does not arise from the rolling of the pieces but is a finisher's fault caused in tentering the pieces out to width. Pieces containing weft out of alignment should not reach the maker-up, because the fault can easily be remedied as most modern tentering machines having a weft straightener designed with the object of bringing the weft at right angles to the warp.

Piece Dyes

" Mr. Warnock devotes two or three paragraphs to the question of rush periods and the shortness of the season from a production point of view, particularly referring to the dyeing end. This is more than an interesting point and it devolves upon the maker-up to help himself as much as possible by ordering his requirements and looking ahead so far as is possible.

" Continuity of production is a vital factor not only in making-up but in spinning, weaving and dyeing, and everything that is possible should be done to spread production over as long a period as possible.

" To install finishing machinery to cover four times the weaving output as suggested by Mr. Warnock is economically unsound and not a practical suggestion. This means over the year that the dyeing plant would stand for nine months. How could you get workpeople for three months work in the year? The whole idea is absurd. Mr. Warnock immediately follows by saying, ' The greatest sin in making-up is to have machinists idle'. Apparently he does not believe that what is sauce for the goose is sauce for the gander.

" Where the manufacturer dyes his own goods there should be no difficulty in finding experienced dyers to carry on the work equally well in rush periods when the manufacturer is overloaded. Where the large maker-up now buys direct from the manufacturer, thus cutting out the merchant or stockist, surely the responsibility for holding of stock should be divided by the maker-up looking well ahead of his requirements and the manufacturer holding a reserve stock in cloths that have been sold to several customers. This refers, of course, to worsted as well as to woollen.

Rayon

" It is suggested that because rayon is synthetic in its origin that it ought to be more regular and more under control than where raw materials are of animal or vegetable origin. The chief chemist of one of our large artificial silk producers gives the following points as worthy of consideration in this connection.

" ' In the process of breaking up into crumbs, also in the ripening room, a maximum temperature variation of a ½-degree must not be exceeded. Chemicals of such purity are required that the rayon manufacturer has further to purify his chemicals in his own works, as the chemical manufacturer's standard is not sufficiently high. In many of the processes humidity and temperature must be automatically controlled within small variation. The size of the particles has

to be tested by the finest sieves it is possible to make and must be less than a thousandth of an inch, otherwise the jets will be choked.'

"He was quite prepared to give many other highly technical details but I thought this was sufficient for us laymen.

"The question of listing is again brought up under the heading of rayon as being very prevalent. I have spent a considerable time in investigating this suggestion and spent an hour with a merchant who deals with some tens of thousands of pieces of rayon annually. He said in the presence of his dyer 'that listing was rarely met with' and on going through his mender books it was found that the percentage of pieces returned for this fault was again, as in the case of worsteds, under ½ per cent. When it does occur it is caused by the piece being slightly out of alignment on the beam or roller that it is wound on to, but this was overcome some years ago by using knife edge beaming, which brings the selvedges into exact alignment on the roller.

"The statement is made that twill linings have been discarded as they contain raw cuttle marks from the heavily pressed finish. Five years ago this was correct but to-day the difficulty has been overcome and from a large stock I chose several pieces at random, perched them and could find no trace whatsoever of the fault. The pieces were beautifully turned out and a credit both to manufacturer and dyer.

Acetate Taffeta

"It is suggested that this would be easier to weave than viscose twill and that it would be easier to obtain accuracy of shade-matching. I do not know on what ground this belief was based as it is certainly not easier to weave than viscose and so far as dyeing is concerned the start was from zero, whereas viscose dyes in a similar way to cotton and known data so far as cotton dyeing was concerned were available. The dyeing of acetate is a slow process as it dyes only when in liquor and continues to dye in the wet state after emerging from the liquor.

"The taffeta cloth weave is the most difficult weave it is possible to think of, which is the probable cause of more weaving faults than in other artificial silk cloths such as twill lining, etc.

"The necessity for good shade-matching is fully realised by the dyer and manufacturer alike and one realises the difficulty occasioned when the dyer of a green lining dyes on the yellow side and the dyer of the cloth on the blue side. The result is anything but harmonious.

"Great help can be given by remembering that the dyer is the man who has the work to accomplish and to see that he has the larger portion of the matching cutting retaining only a small portion for the latter purpose, also wherever possible to let the dyer have a cutting in a similar material to the one he is actually dyeing. Where a wool cutting is sent for instance, as the shade of the dyeing of the lining the dyer is usually willing to submit laboratory dyed cuttings for approval and standardisation. Where the pieces are occasionally dyed too far off colour it is sometimes possible to dye them up to dark shades such as black, navy or nigger and re-dye to original shades.

Rayon Dress Cloths

"Mr. Warnock points out that certain dull finish cloths come up bright particularly in dark colours. It is quite correct that all dark colours in delustred artificial silk appear to be brighter than light colours. Dullness in a bright finish cloth is usually a finisher's fault and with a good finisher there should be no difference, that is no appreciable difference, between various shades.

"Mr. Warnock also mentions the difficulty of weft bars when the weaver has re-shuttled. To say that there is a weft bar with every stoppage of the loom is a gross exaggeration. Usually this fault is caused not by a speed increase of the loom but rather careless tuning of the taking-up motion. Artificial silk piece goods, as is pointed out, are usually examined in a horizontal position. This

method is quite effective if properly carried out and should be done in a good North light or a well light.

" In conclusion, perhaps the best reply that could be given to the statements made that British manufacturers of textiles have fallen to such a low ebb is this; that in order to meet requirements of shipping markets manufacturers are continuously compelled to increase their selvedge harness plant, for the purpose of weaving into the selvedge the words, 'BRITISH MANUFACTURE,' and importers are willing to pay 3d. to 9d. per yard for name selvedges proving that goods are British manufacture because they can then obtain a higher price on account of the guarantee of excellence. The finger cannot be pointed to any country in the world who can produce goods of the same high grade and standard as those made in England.

" Whilst refuting strongly the volume of faulty pieces I do not wish in any way to detract from the usefulness of the presentation of the effects of such faults in the making-up of the garment, and I hope with Mr. Warnock that all who read his lecture will feel impelled to tighten up their methods and effect an improvement of their individual standards."

Correspondence

THE STRUCTURE OF KERATIN FIBRES

To the Editor.

SIR,

According to Astbury and his co-workers, hair and wool consist essentially of a backbone structure of polypeptide chains which is extended in stretched fibres and folds up again when the fibres shrink to their original length. This folding is supposed to proceed further when the fibres are caused to supercontract. The folding up of the extended polypeptide chains is said to be prevented when the fibres are given a permanent set.

The amount of extension imparted to the polypeptide chains was first taken at 29 per cent. by Astbury and Street (*Phil. Trans.* A, **230**, p. 87.) but was afterwards taken to be 100 per cent. because hair was found to be extensible to the extent of 100 per cent. *Loc. cit.* p. 101.

Speakman (*J. Soc. Dyers and Col.*, 1936, **52**, p. 335) stated that the permanent set of hair and wool is released by caustic soda, yet on page 340 of the same journal he stated that caustic soda does not attack those linkages which are responsible for permanent set. Apparently the latter statement was made because Astbury had observed that the contraction of permanently set fibres caused by caustic soda is not accompanied by a reversion from beta to alpha keratin. Since caustic soda does actually cause shrinkage of permanently set fibres, one can only conclude that the shrinkage is not due to the folding of polypeptide chains.

Astbury and Woods (*J. Text. Inst.* 1936, **25**, p. 246) stated that boiling 5 per cent. bisulphite causes a change from alpha to beta keratin, corresponding to a lengthening or straightening out of the folds in the polypeptide chains, yet boiling bisulphite causes supercontraction under the conditions adopted.

One is thus led to the conclusion that the conversion of alpha keratin to beta keratin does not depend on the stretching of keratin fibres or of the polypeptide chains said to be present in them. The X-ray spectra do not in themselves prove that the molecule of keratin present in normal hair and wool and termed alpha keratin is extended when it is converted to beta keratin whether by stretching or compressing the fibres or by converting them by chemical means. The X-ray spectra merely show that the spacings found in normal hair and wool are different from those found in the same fibres when extended, compressed laterally or chemically treated, and that this difference is such, that spacings substantially along the axis are multiples of 5·1 in alpha keratin and multiples of 3·4 in beta keratin.

It is not impossible that the change may be due to the distortion of a rectangular cell of dimensions 27 Å U × 10·3 Å U × 9·8 Å U to a monoclinic cell of the same dimensions with the angle γ about 42°.

Drawings are given to illustrate this.

In Fig. 1 a unit cell is given for alpha keratin in accordance with Astbury's calculations. The crystal of alpha keratin is, however, by no means so perfect as the figure indicates. The arrow and dotted line indicate how these rectangular cells might be distorted to monoclinic cells.

In Fig. 2 there is shown the monoclinic cell ABCD and it is clearly seen that as far as symmetry is concerned this is identical with the rectangular cell AXYC which has the same relative dimensions as the rectangular cell calculated by Astbury.

The large circles indicate atoms connected to strongly reflecting side chains probably of peptide type and the small circles indicate atoms connected to other

side chains all of which are normal to the plane of the paper as in Astbury's own suggestion.

From the points already discussed it would appear that the folding and unfolding of polypeptide chains is not the cause of supercontraction or of the shrinkage of permanently set fibres by alkalies, and some other explanation of these phenomena must be sought.

By treating hair and wool in certain ways (compare Cunliffe, *J. Text. Inst.*, 1933, **22**, T417) and examination in the microscope it is easily observed that the cortex is mainly fibrillar. The cuticle is, however, definitely not fibrillar,

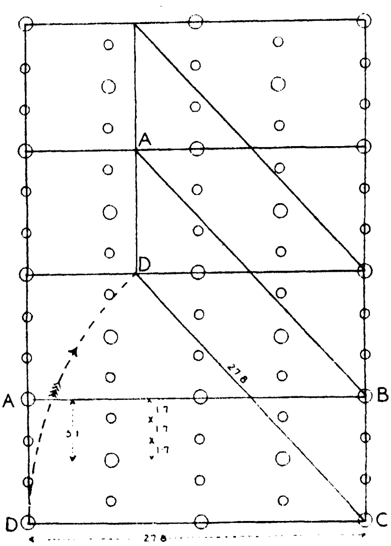


FIG 1

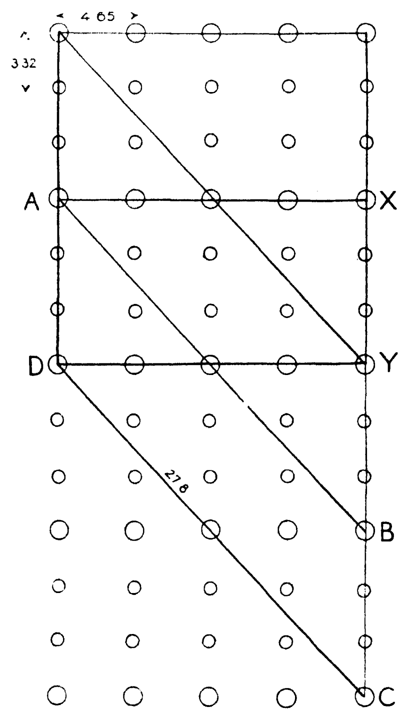


FIG 2

it is of network structure and shows no orientation in its X-ray spectrum. Thus without considering chemical structure one can regard a hair as a cylindrical tube of network structure filled with solid matter of fibrillar structure. Speakman made a similar suggestion in 1927 (see *Proc. Roy. Soc.* B, 1928, 103, p. 377) to explain the plasticity of wool. In such a system the softening of the interior followed by stretching of the whole structure with subsequent hardening of the interior would produce permanent set. Further softening of the interior by caustic soda would release this set but would not bring the interior substance back to its original condition. There are other ways in which permanent set might be caused in such a system.

If the contents of the tube could be swollen laterally without altering the cylindrical external network or if the contents could be swollen more rapidly than the external network the latter would shrink lengthways. This is a possible explanation of supercontraction as caused by steam in Astbury and Woods' experiment. If both contents and cylindrical network were swollen and the complex then dried, any resistance offered by the contents to the free diametrical shrinkage of the outer network would cause the latter to shrink lengthways

whereas if the drying could be arranged to take place equally throughout the mass no such shrinkage lengthways should occur.

As an illustration of this, Speakman has shown that hair boiled 30 minutes in 5 per cent. bisulphite suffers little change in length but it swells considerably in diameter and when dried in air the fibres supercontract about 30 per cent.

The writer has been able by carefully controlled drying at room temperature without tension, of fibres boiled 30 minutes in 5 per cent. bisulphite to reduce the shrinkage to 2 per cent. In other words when the drying is carried out equally throughout the mass no appreciable supercontraction occurs. But in spite of the fact that the dimensions of the fibres remain unchanged, the keratin passes from the alpha to the beta form but not completely disoriented as when considerable shrinkage is permitted.

Thus the conception of a long chain polypeptide backbone molecule having an inherent tendency to shrink, held rigid by the cross linkages (salt and disulphide linkages) becomes difficult to accept for alpha keratin, and Speakman's theory of supercontraction which is based on the above conception is disproved by the experiment described.

It is not suggested that sulphur linkages and salt linkages play no part in these phenomena, they most probably have much bearing on the problems of swelling, but the phenomena of supercontraction and of permanent set are not controlled by any one linkage ; supercontraction effects can be produced by other swelling agents not having any specific action on disulphide linkages and permanent set can be prevented by reagents having no affinity for either sulphur or amino groups.

The properties of the cuticular layers can best be accounted for by assuming that the cross linkages are mainly resistant peptide linkages. It appears certain that the elastic properties of hair and wool are dependent on the cuticle. (Compare Speakman, *Proc. Roy. Soc.*, B, 1928 **103**, p. 377.)

This receives further confirmation from the observation first made by Astbury and Street (*loc. cit.* 95) that when hair is treated with sodium sulphide the cuticle can easily be extended 100 per cent. whilst the cortex consisting of fibrils is dissolved. Also it is well known that the elastic properties of wool and hair are permanently changed if they are extended more than 30 per cent. Speakman *loc. cit.*

Kilmacolm. (*Signed*) W. HARRISON.
4/5/37

Reviews

Nachweis und Bestimmung von Lösungsmitteldämpfen. Von Dr. Ing. L. Piatti, Berlin. VII, 88 Seiten, 22 Abbildungen (Technische Fortschrittsberichte Band 40). Dresden, 1937, Theodor Steinkopf. Preis R.M.6,50, geb. R.M. 7,50.

Dr. Piatti's book on the detection and determination of solvent vapours presents for the first time in an orderly manner the diverse information available on this subject. Its scope may be judged from the headings of the sections which are as follows: the occurrence of solvent vapours; the need of detecting these vapours; the technique of sampling; detection and determination of solvent vapours; determination of explosibility of mixtures of solvent vapour and air; reactions of various solvents; the determination of solvent mixtures. The sections dealing with detection, determination and reactions of the various solvents are presented in logical sequence, general principles being adequately discussed before the introduction of special applications. In the latter connection descriptions are given of a selection of commercial instruments. It may be noted, however, that no reference is made to the F.M. Continuous Flammable Vapour Indicator or to the McLuckie Gas Detector which are largely used in the U.S.A. and in this country, respectively, for the quantitative measurement of inflammable vapour concentrations in air. The solvents specifically dealt with are amyl alcohol, amyl acetate, ethyl ether, ethyl methyl and isopropyl alcohols, acetone, petroleum spirit, oil of turpentine, benzene, decalin, tetralin, cyclohexanol, carbon disulphide, methylene chloride, carbon tetrachloride and trichlorethyene. The following solvent mixtures are also briefly dealt with, alcohol-ether, alcohol-ethyl acetate, alcohol-benzene, alcohol-toluene, acetone-alcohol, acetone-alcohol-benzene, petroleum spirit-benzene, petroleum spirit-carbon tetrachloride, pyridine in solutions and traces of carbon disulphide in benzene and carbon tetrachloride. References to original papers bearing on the subjects discussed are adequate and largely compensate for the brevity of treatment. Author and subject indexes are provided. The book is recommended to all who are interested in problems connected with the presence of solvent vapours in air whether from the point of view of hygiene, fire and explosion risk, control of manufacturing operations or solvent recovery.

J.S.H., H.B.B.

Betriebseinrichtungen und Betriebsüberwachung in der Textilveredlung. Professor Dr. -Ing. Otto Mecheels (Julius Springer, Berlin, 1937. Pages v + 122, with 67 figs. Price, R.M.13.80).

The title may be rendered "Works organisation and control in textile processing." It would seem at first sight a very ambitious undertaking to attempt to deal with such a large subject in a space of rather more than a hundred pages. Indeed, if the book were planned as a detailed work of reference, it would clearly be impossible; if the attempt were made to summarise in that space everything of importance relating to the subject it would be too compressed to be valuable. But this book follows an intermediate and rather unusual plan. Different parts of the subject are treated with varying degrees of detail. The chief aim seems to be to give the underlying principles of organisation and management, but the more important and interesting of these are illustrated by detailed examples. The author points out that these are not necessarily for exact imitation, but may be modified to suit local needs. This method of presenting the subject, while making some demands upon the intelligence of the reader, makes possible a great saving of space.

The first section deals with construction and maintenance of the buildings. The requirements of these differ in many respects from those in other branches of the textile industry. The general principles of construction and of the planning of the distribution of space are given, with such details as the arrangement of the complicated network of pipes carrying steam, gas, compressed air, raw water, softened water, etc. (which are recommended to be painted in different colours to avoid confusion). Other topics in this section are protection against fire, types of paint to prevent corrosion and artificial lighting for various purposes. In the next section a very clear idea is given of the properties desirable in a water supply and how these can be obtained. There are descriptions of softening

by base-exchange, lime-soda and trisodium phosphate. Considering the importance of the cold lime-soda process for water which is not subsequently to be heated, it is rather surprising that the author does not refer to the great improvements made in this recently by the addition of sodium aluminate. Water treatment with sodium metaphosphate might also be discussed with advantage. Sections are devoted to heating, steam production and the removal of mist from the atmosphere, and also to the properties of materials suitable for the construction of plant. Instruments for the control of bleaching, dyeing, mercerising, etc., are described—thermometers, pressure gauges, flow-meters, clocks, balances. Useful discussions are given of the best arrangements for works and chemical stores, mercerising plants and dyehouses. Accident prevention is considered. A section of practical " wrinkles " is given. The final quarter of the book deals with theories and methods of calculating the depreciation of plant.

Each of the topics listed above might easily form the subject of a complete book, but the author gives the essentials of them with no irrelevancies. The style is compact and clear, and great use is made of diagrams and photographs to replace written descriptions. Nearly one-quarter of the space in the book is occupied by the figures. The photographs are well reproduced and the book has the attractive appearance to which one is accustomed in publications from Julius Springer. The result is a work of direct appeal to the practical man, which can be thoroughly recommended. It is to be hoped that it will be available soon in an English translation. A.F.H.W.

Synthetic Rubber. By W. J. S. Naunton. Introduction by Prof. Sir William Pope, F.R.S. Published by Macmillan & Co. (pp. xvi and 162. 7/6 net).

In this very readable book Dr. Naunton first traces the history of synthetic rubber from the work of Williams in 1860, through the pioneer efforts of Sir William Tilden to the production on the manufacturing scale of polymers of chloroprene and butadiene. The subject is then discussed from the economic point of view and it is recognised and freely admitted that no synthetic rubber can compete in price with the natural product. There is, therefore, no justification for the production of a synthetic material unless it possesses properties which make it superior in some ways to plantation rubber.

The chapter on the chemistry of synthetic rubber is divided into two parts dealing respectively with the production of the parent hydrocarbon or substituted hydrocarbon and its polymerisation. Butadiene may be obtained from mineral sources, directly from mineral oil or coal and indirectly from acetylene, coke and lime being used for the necessary carbide. It may be obtained also from foodstuffs such as grain or potatoes, which are used as the source of the alcohol. Very interesting figures comparing the possible productions of rubber from land under rubber trees and under potatoes are given. Neoprene and the Russian Sovprene are also produced from acetylene, the parent substance of the former being chloroprene. The polymerisation processes appear to be more difficult to control than the syntheses of the butadiene and chloroprene.

Chapters dealing with the physics of synthetic rubber and its technology are followed by one giving its applications. Synthetic rubber latex is separately treated. The book closes with a short chapter on " Future Outlook " in which some of the many problems still unsolved are mentioned. T.

Wool. (5th Edition.) By S. Kershaw, F.T.I. Published by Sir Isaac Pitman and Sons Ltd. (p. 123. 3/- net).

The fifth edition of this book on wool in Pitman's Common Commodities and Industries series has a new author who is well known to readers of the Textile Institute *Journal*. In his preface Mr. Kershaw states that he has not included the latest findings of the scientific research workers engaged in wool. The bibliography he appends, however, will afford excellent direction for those who wish to read farther into the subject.

Mr. Kershaw's opening chapter " A Hand Test with Wool " leads in a logical fashion to the brief descriptions of the manipulation and fabrication of wool. In a book of this size the treatment of these branches of the subject must necessarily be very sketchy.

Wool production is treated in the body of the book. The historical treatment is interesting and so is the tracing of the connection between the ancestors of

sheep and the highly bred flocks of to-day. The various types of wool are adequately dealt with on a geographical basis. Of very great interest are the figures showing the enormous increase in wool production in Australia between 1920 and 1934. The application of biological science appears to be a highly profitable investment in this case. The growth of the wool industry in Australia from nothing to over 1,000 million lbs. per annum in less than 150 years must be one of the most romantic stories in the history of human achievement. The economics of wool are briefly sketched in the chapter headed " From Shearing to Saleroom."

In the discussion of wool and hair properties the determination of fineness and crimp and the fundamental structure as revealed by X-rays are briefly described. The tables giving quality number, fineness and crimp are interesting and useful.

T.

Manchester Makes : A Survey of Lancashire Manufactures other than Cotton. Manchester Chamber of Commerce. (3/6.)

This account of the industries, other than cotton, carried on in the industrial area of South-East Lancashire and North-East Cheshire, should certainly succeed in its object of encouraging the home and export trade in Lancashire. Its compilation has been made possible through the generous benefaction of Mr. Bruce Macpherson, who thus desires to perpetuate the memory of his father, the late Mr. Evan S. Macpherson. The list of contents shows at a glance the breadth of Lancashire's industrial interest which will certainly surprise many people. The brief accounts of the various industries make interesting reading. The classified list of manufacturers gives the volume a permanent value as a work of reference, and this value is increased by the explanation of the purpose of the list and the notes on how to use it. T.

Additions to the Library.

Rayon Staple Fibr Yarns. Howard and Bullough, Accrington.

This booklet deals with the preparation and spinning on cotton spinning machinery of viscose rayon staple fibre yarns and of mixtures of staple fibre and cotton. Baer Sorter diagrams at each stage of manufacture are given and the lea and single thread tests are given in tables and as graphs. The effects of filament denier (or hair weight per centimetre) and length of staple for 100 per cent. rayon staple fibre yarns are similarly exhibited. Data showing the effect of twist on the strength up to 60 turns per inch are provided. The differences between single ring spun, double ring spun and two fold ring doubled yarns are discussed.

Mixtures of staple fibre and wool processed on worsted machinery are similarly treated. The difficulties encountered in the spinning of acetate staple fibre are mentioned and it is expected that these will ultimately be overcome.

The Production of Fast Solid Shades on Wool and Viscose Staple Fibre mixture fabrics. Imperial Chemical Industries Ltd.

This pamphlet contains instructions for the use of Soledon (solubilized vat dyes) dyestuffs. A typical recipe, details of the mechanical processes, three patterns and list of dyestuffs applicable are given.

World Consumption of Wool, 1936. Printed and published by H.M. Stationery Office for the Imperial Economic Committee, 2/6.

This publication prepared in the Intelligence Branch of the Imperial Economic Committee summarises for the year 1936 the contents of the Committee's monthly " Wool Intelligence Notes " and brings up to date the Committee's survey " World Consumption of Wool, 1928-35 " which appeared in March, 1936.

General Items and Reports

National Certificates in Textiles

The Board of Education have issued the following particulars in relation to the previous full-time school education of candidates for National Certificates in Textiles at the Examinations held in 1936.

Type of previous full-time school education	Ordinary Certificate				Higher Certificate				Grand Total			
	No. entered	No. passed	No. failed	Percentage of Passes	No. entered	No. passed	No. failed	Percentage of Passes	No. entered	No. passed	No. failed	Percentage of Passes.
1	2	3	4	5	6	7	8	9	10	11	12	13
Public Elementary School (including Central School)	77 (62·1)	47	30	61·0	44 (64·7)	38	6	86·4	121 (63·0)	85	36	70·2
Secondary School (including Public School)	45 (36·3)	38	7	84·4	22 (32·4)	21	1	95·5	67 (34·9)	59	8	88·1
Junior Technical School	2 (1·6)	1	1	50·0	2 (2·9)	1	1	50·0	4 (2·1)	2	2	50·0
Totals ...	124	86	38	69·4	68	60	8	88·2	192	146	46	76·0

The figures in brackets represent the percentage of the total number of candidates entered for the Certificate indicated.

NEOPRENE EXHIBITION

When the world supply of natural rubber far exceeded the demand, the search for a synthetic product possessing the properties of natural rubber appeared to become futile. To justify economically the continuance of the laboratory work, the chemists had to modify their programme and to endeavour to find a substance which would in some respects be superior to plantation rubber. Neoprene, a polymerised chloroprene, is such a material.

From April 26th to May 1st, the Imperial Chemical Industries Ltd. held an exhibition of Neoprene at the offices of the Federation of British Industries, 21, Tothill Street, S.W.1. Articles made from Neoprene were on view with the object of showing the many possible applications of this synthetic material. Lectures were delivered on various aspects of the subject of artificial rubber. The story of synthetic rubber beginning with the work of Williams in 1860 was told by Dr. Naunton. Mr. M. Jones discussed the processing of Neoprene and Dr. Flint dealt with Neoprene latex and its applications. Mr. Clarke and Mr. Oriel described the general industrial uses of Neoprene and its application to the petroleum industry respectively.

The processing of Neoprene appears to be simpler than that of natural rubber. Neoprene has a greater resistance to the deteriorating influences of heat and of various oils than natural rubber possesses. The field of application of Neoprene is much wider than that of rubber, which has resisted the many effects to increase world consumption in order to absorb the excess production. The chemical and textile trades offer many opportunities for the exploitation of Neoprene, as do also the engineering, automobile, aircraft and electrical industries.

THE JOURNAL OF THE

TEXTILE INSTITUTE

Vol. XXVIII JUNE 1937 No. 6

PROCEEDINGS

"SERVICEABILITY OF FABRICS FOR CLOTHING PURPOSES"

Annual Conference of the Institute, Southport, 9th, 10th and 11th, June, 1937.

The Conference for 1937 was held at the Prince of Wales Hotel, Southport. Members with their wives, relatives and friends began to assemble during the afternoon of Wednesday, 9th June. A Conference office had been opened in the Hotel from which each arrival secured advance copies of the contributions to the Discussions of Thursday and Friday, badges, and other information relating to the event. An Exhibition, to which fuller reference will be found on a subsequent page, was set out in the Assembly room of the Hotel and early-on visitors began to inspect the Exhibits.

The Conference may actually be said to have commenced with a reception and dance at the Floral Hall on the Promenade on the Wednesday evening. The President, Mr. John Crompton, and Mrs. Crompton welcomed those attending and one side of the large Hall had been set aside for the Institute party. Those who wished joined the dancers on the floor and refreshments were provided by the Corporation. The Mayor of Southport (Councillor H. W. Barber, J.P.) arrived during the evening and was introduced to the President and many of the members present. No speeches were included in the programme which was purely one of dances and this afforded excellent opportunity for members to get together in conversation and to establish the atmosphere of unity of purpose so essential to the success of a Conference.

Thursday, 10th June. First Conference Session.

The proceedings were opened on Thursday morning in the Banquet Hall under the guidance of the President. The Mayor was present and welcomed the Institute to Southport. He commented on the excellent weather in which the event had been begun and hoped those present would believe Southport deserved its claim to be called "Sunny Southport." He made reference to various aspects of the Institute's work, noticing its Competitions, Scholarships and interest in Research. Expressing the view that all these activities were calculated to be of benefit to the Textile Industries Councillor Barber hoped everyone in attendance would enjoy their stay in Southport and re-visit the resort at not too distant a date.

Mr. Crompton thanked the Mayor not only for being present to welcome the Institute that morning but for the entertainment that had been provided at the Floral Hall the previous evening. He made reference to the direct link between the prosperity of seaside resorts such as Southport and the general prosperity of the Industries from which visitors came, and expressed the hope that Southport's prosperity would march in step with that of Lancashire and other textile centres. Mr. Crompton then asked Mr. F. Schofield of the College of Technology, Manchester, to take the Chair and open the serious business of the Conference.

Mr. Schofield did so, and after some introductory remarks called upon Mr. C. M. Whittaker of Courtaulds Ltd. to open the Discussion. Mr. Whittaker referred in general terms to various aspects of the subject of serviceability of fabrics emphasising some of the points he had included in a paper* that had been set up in type and distributed in advance to all in attendance. Other speakers, some of whom had previously supplied written contributions* to the discussion, also took part in the animated and interesting discussion which followed. Mr. Whittaker replied to points raised and the session was brought to a close by the coming of lunch time.

The Thursday afternoon was left free, so far as organised excursions were concerned. The Conference committee felt that Southport, of itself, offered sufficient attractions to content the members and this proved to be an accurate estimate. Visits to the Aquarium and to an Exhibition of Alpine plants proved attractive and, though not too hot, the weather continued bright and sunny.

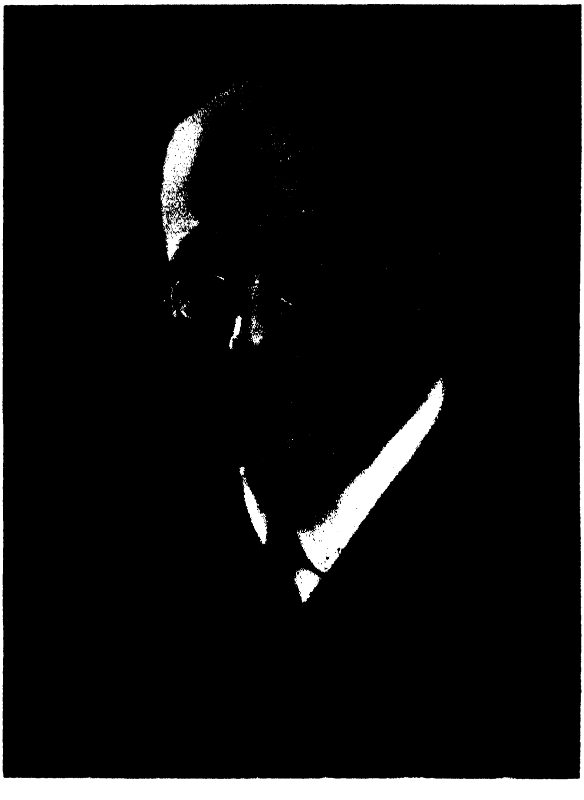
Conference Banquet, Thursday Evening, 10th June.

This is now an item of real importance in the Conference programme. It offers an opportunity to invite representatives of other Societies and Organisations to join with Institute members, thus emphasizing the policy of the Institute in securing co-operation in pursuit of its objects. The speech from the principal guest at the Banquet has been looked upon as an occasion when an authoritative view of the Institute's work from someone looking at it from the outside can be secured. This was the object in the invitation to Sir Frederick Marquis, Managing Director of Lewis's Ltd. to be chief guest on this occasion. Apart from this, it must also be pointed out that Sir Frederick is President of the Drapers' Chamber of Trade, whose hospitality at the London Conference last year will not soon be forgotten. In a very attractive and polished speech Sir Frederick proposed the Toast " The Textile Institute," and in a humorous introduction expressed some wonderment as to why he had been invited to the place he then occupied as proposer of that toast. He surmised that he might perhaps be regarded as an exhibit and thought that though he could not come up to any expectation that he would speak with the tongues of men or of angels he might at any rate be expected to speak as one who knew all about the profits. Profits, he believed, had been a sight for sore eyes in the Textile industry.

Sir Frederick next made reference to the general question of the relationship of the retail buyer and the manufacturer in regard to prices. He said that the distributor did not want to keep down prices at a level at which the producer could not make a profit, a reasonable profit. His buyers were instructed not to place orders which would not give the manufacturer a reasonable profit. As between the manufacturer and the distributor he was certain no good could come from mutual condemnation. They had, in some way or other to get together and he could not but wish that the Industry generally would read the Institute's charter again. In technical matters a very high pitch of efficiency had been reached ; the *Journal* published by the Institute was first class. The standard of technical education in textiles was an object lesson to all and in original research the Industry lead the world.

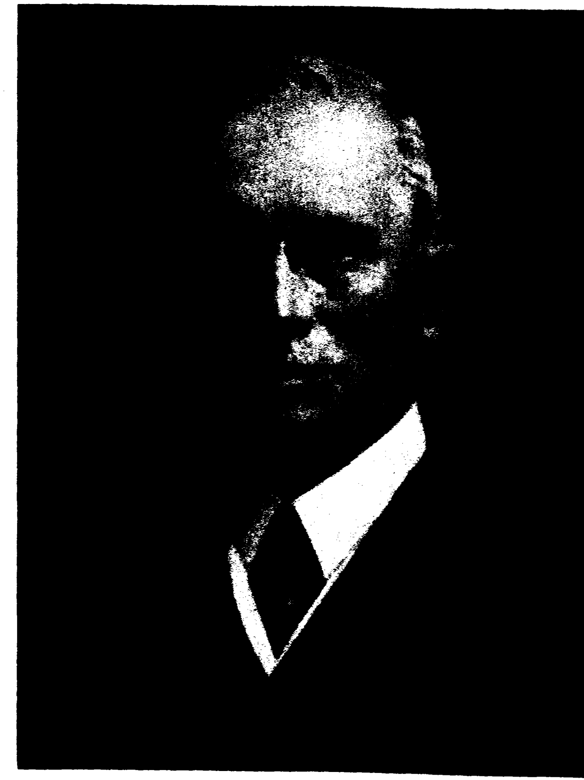
The fundamental issue as he saw it, continued Sir Frederick, was to get together in regard to standards. This co-operation had been achieved in the building trade, in the engineering trade and in the chemical industry. In other countries textile standardisation matters were also being tackled. But in this country, and particularly in regard to the finished article, the public were left in complete ignorance. The retail trade, he reminded them, perhaps in a misguided fashion had made an effort and had produced definitions and attempted

* This paper with other contributions to the Discussion will be printed in full in the July issue of this *Journal*.



Sir HAROLD HARTLEY
who delivered the " Mather " Lecture,

Mr. W. H. Webb
who received the Institute Medal.



Mr. John Emsley
who received the Institute Medal.

some standards. He ought perhaps to be glad this had been done but he would have preferred to have seen such work as the outcome of a co-operative effort on the part of manufacturers and distributors. He pointed out that both these great sections of the textile industries had to live together and that both were trying to get a living by serving the public. He was sure they would make a better living by a better understanding of each other's problems.

Mr. John Crompton, the President, responding to the toast, thanked Sir Frederick for the kind things he had said about the Institute. He assured him that the Institute would use every endeavour to secure all-round co-operation in those matters to which reference had been made and which came within the purview of the Institute. He asked Sir Frederick to believe that the Institute did not confine membership to the production end and its meetings provided opportunity for the presentation of more than the producer's point of view. Mr. Crompton complimented Sir Frederick upon the broad outlook he had manifested in regard to employment conditions and expressed the wish that other employers would emulate this example. On Standardisation problems he said that everything that the Institute could properly do was to be undertaken and he felt from his own observation of that morning's discussion that the right men were available, fully capable of giving the best advice in all matters affecting quality and serviceability.

Awards of the Institute Medal.

The next event in the after-dinner programme was the presentation of the Institute Medal to Mr John Emsley of Bradford, and Mr. W. H. Webb of Randalstown. Introducing Mr. Emsley to the President for this award, Mr. J. H. Bates of Wakefield said :—

" May it please you, Sir, It is my privilege to present to you, John Emsley, a Citizen, and a Justice of the Peace for the City of Bradford.

" Beginning in life with few material advantages, but endowed by nature with health and strength of body and mind and through the influence and guidance of a good Christian Mother, he has made for himself a position and a name, which are respected and honoured for tenacity of purpose, firmness of principle, business integrity, and he is second to none in the place which gave him birth.

" He is Principal and Governing Director of five great Industrial Wool Textile Concerns, which altogether employ 3,000 people ;

" A Local Director of the Union Bank of Manchester ;

" A Member of the Council of the Bradford Chamber of Commerce, for two years its President, and now its Treasurer ; Chairman of its Manufacturers' Section, the Chamber's Representative on the Local Employment Committee, and at one time a Member of the Advisory Committee of the Board of Trade.

" The Textile Institute of which he was President for four years, elected him its First Fellow in recognition of the Charter which it obtained largely through the influence and perseverance of John Emsley.

" In 1913/14 he was President of the Bradford Textile Society.

" During the War he was Vice-Chairman, in Bradford, of the Lord Derby Scheme, also Military Representative, and since then Chairman of the King's Roll Committee.

" In Social Life he has been President of the Bradford Cricket Club, the Automobile Club, and Toc H ; he is also a prominent Member of the Rotary Club.

" He has taken an active part in Religious work, and has been connected with the Wesleyan Church throughout his life.

" In Politics he is a Liberal, and for five years he acted as President of the Bradford Liberal Federation.

" He is a Member of three London City Guilds, viz :—The Woolmen's, the Weavers, and the Clothworkers Companies.

" I commend John Emsley, as a fit and proper person to receive at your hands, the greatest honour that the Textile Institute can bestow upon one of its most distinguished Members."

Mr. Crompton, handing the medal to Mr. Emsley, said it gave him great pleasure to do so not only because of his long friendship with Mr. Emsley but also because as Chairman of Council he had been associated with him during the time that efforts were being made to secure the Royal Charter.

Mr. Frank Nasmith, Hon. Secretary of the Institute, who presented Mr. W. H. Webb for the Medal, said it was unfortunte that Mr. Webb was in the United States and could not be there to receive the award personally. It was still more unfortunate that a representative of Mr. Webb's firm, who had been deputed to attend in his stead, had been called away unavoidably and that in consequence no one could actually receive the medal on Mr. Webb's behalf. He proposed, therefore, with the President's consent, to take it himself and make subsequent arrangements for it to be handed to Mr. Webb on his return from America. Addressing the President in regard to Mr. Webb, he then said :—

" Mr. President, I present to you William Hubert Webb, a Fellow and a Foundation Member of this Institute, as a worthy recipient of the Textile Institute Medal. The Medal is an award in recognition of distinguished services to the textile industry and particularly to the Institute and its work. The claims of Mr. Webb are remarkably strong in both connections. In his capacity of Chairman of the Old Bleach Linen Co. Ltd., he has demonstrated a subtlety in publicity methods which has even taught a great deal to the past masters of trumpet blowing in the United States of America. His quiet effective and artistic methods weaned the housewife from her use of table mats to table linen.

" His great work for the Linen Industry, extending over many years, is recorded in the offices he has held. He is an Ex-President of the Irish Linen Society, Ex-President of the Belfast Linen Merchants Association, and Ex-President of the Belfast Chamber of Commerce. He took a prominent part in organising the first Irish Linen Guild and was one of the chief movers when the Irish Linen Research Institute started at Lamberg, Co. Antrim. He is still an active member of the Council of that Institute and also of various Committees. During the War he was a member of the Flax Control Board. With all his manifold activities he has still found time to play an extremely active part in the advancement of the interests of the Textile Institute through its North of Ireland Section. He has been Chairman of this Section since 1926. His attendance at its meetings has been practically 100 per cent., and his sage counsel has been invaluable. He is ever conscious of the need to foster the young people of Industry, and was personally noted at Cambridge addressing the Drapers Summer School on the Flax and Linen Industry.

" He is a Deputy-Lieutenant for Co. Antrim. He has not sacrificed exercise to the calls of business and public work. No doubt his dexterity and the concentration, so highly essential, which enabled him some years ago to secure the Irish Amateur Golf Championship on two occasions, has in later life taught him how to shoot straight to his objective without wasting any strokes.

" Mr. President, I present to you William Hubert Webb, having, I hope, convinced you that he is undoubtedly worthy to receive the Medal which we guard so jealously."

The Toast of " The Guests " was proposed by Mr. George Haigh of Bradford and responded to by Councillor H. W. Barber, J.P., Mayor of Southport. Dancing followed the conclusion of the speeches.

Second Conference Session: Friday, 11th June.

This session commenced on Friday morning at 10 o'clock and the Chair was occupied by Mr. B. H. Wilsdon, Director of Research of the Wool Industries Research Association. He called upon Dr. F. T. Peirce of the British Cotton Industry Research Association who had contributed an introductory paper* on wear-testing. Other contributions* to a very general and earnest discussion were made by over thirty speakers and every evidence was there of the great interest taken in the subject as well as of the breadth of the field of work in this subject.

The "Mather" Lecture, Friday, 11th June.

This lecture,* inaugurated in memory of Sir William Mather, a past President of the Institute, was delivered by Sir Harold Hartley, C.B.E., F.R.S., M.C., Vice-President and Director of Scientific Research of the London, Midland and Scottish Railway Company. Sir Harold's subject was "Agriculture as a potential source of Raw Materials for Industry?" The Chair was occupied by Principal B. Mouat Jones, D.S.O., of the College of Technology, Manchester, who introduced the lecturer as an old personal friend and one outstandingly qualified to present such a subject. The lecture was illustrated by slides and at the conclusion a unanimous vote of thanks was accorded to Sir Harold Hartley on the proposal of Mr. S. E. Ward of Nottingham, seconded by Mr. Frank Nasmith.

Members present then had afternoon tea as guests of the Council.

Exhibition of Testing Apparatus.

During the Conference period an Exhibition of Wear Testing apparatus and of samples, diagrams, etc., bearing on the Serviceability of fabrics, was open in the Assembly Room of the Hotel. The Exhibition aimed at providing illustration of the tests applied to textile materials in attempts to evaluate their "performance" values. The testing of fabrics for durability or resistance to wear has been the subject of considerable investigation and the exhibits collected on this occasion for the first time were indicative of the variety and ingenuity of the devices planned to carry out "wear" tests. Exhibitors were :—

The British Cotton Industry Research Association, who showed a series of photographs and apparatus for testing stiffness, thickness, function and brittleness ;

The British Launderers' Research Association, who showed garments and portions of garments to illustrate types of failure and of shrinkage ;

The Department of Textile Industries, Leeds University, who showed a wear-testing or rubbing machine ;

J. H. Lester, Esq., of Tootal Broadhurst Lee Co., Manchester, who showed a ring-wear testing machine ;

The Linen Industry Research Association, who showed a Cloth wear testing machine, a photometer for the measurement of lustre, an apparatus for testing the resistance of linen shoe fabrics to repeated creasing, and apparatus for measuring the fastness to rubbing of dyed materials ;

The College of Technology, Manchester, who showed a wear testing instrument ;

The University of Nottingham, who showed an abrasion testing machine ;

The Wool Industries Research Association, who showed a wear testing machine ; and examples indicative of fastness testing, shrinkage measurement, and detergent efficiency ; and

Messrs. H. E. Messmer, London, who showed an example of the Schopper abrasion tester.

---

* To appear in full in the July issue of this *Journal*.

Irish Section

CO-OPERATION BETWEEN THE TEXTILE AND LAUNDRY INDUSTRIES

By F. Courtney Harwood, B.Sc., F.I.C., M.I.Chem.E.
Director of Research, British Launderers' Research Association.

A paper given to the Irish Section of the Textile Institute at Belfast on March 18th, 1937.

This lecture is an endeavour to describe the efforts which have been and are being made in the laundry industry to place processes and investigations on a fundamentally sound, scientific basis, to indicate the kinds of faults that arise, and to suggest that co-operation along those lines which have already been adopted in part, will go a long way to remove a certain spirit of *laissez-faire* and even of animosity, which may have existed in past years between the textile industry as a whole, and the laundry industry. All sections of industry have a common goal—to give satisfactory service to the general public—and that goal, I am sure, can be won only by united and co-operative efforts.

The laundry industry, although a very old one, was not organised until 1886, when the National Launderers' Association was formed in London. This Association suffered several changes of name, similar Associations were formed in other parts of the country, and eventually in 1920, the National Federation of Launderers, Ltd., came into being. Owing to the enlarged scope of its work and its increasing prestige, this body with the permission of the Board of Trade, changed its name to the Institution of British Launderers, Ltd. last year.

During the past few decades, when the trade body has been increasing in prestige, there has been considerable re-organisation, rapid expansion, and, in some directions, almost incredible progress within the trade itself. Old-fashioned, badly ventilated laundries are dying out, giving place to large, well-planned and airy factories wherein the comfort of the workers is of prime importance. Coincident with the developments thus briefly outlined, laundering has become more scientific, particularly on the process side. In this evolution, the British Launderers' Research Association has played an important part.

The British Launderers' Research Association is one of a group of industrial research associations formed under the ægis of the Department of Scientific and Industrial Research at the end of the war, and is constituted in exactly the same manner as the Linen Research Association. It was formed in 1921, when work was commenced in a small temporary laboratory. The total income for the first financial year of the Association was approximately £5,000. For the current year, it is estimated that it will exceed £10,000. The original Articles of Association limited membership to commercial launderers and dry cleaners; an alteration effected last year now permits of other classes of membership; viz :—manufacturers, processors and distributors of textiles, manufacturers of laundry machinery and materials and laundries owned by public bodies, hospitals and institutions. This admission of members of the textile industry, is a big step forward towards co-operation.

The permanent laboratory was ready for occupation in 1923 and an experimental laundry was added in 1926. A bungalow on a freehold site adjoining the laboratory was purchased and occupied in 1933, whilst an upper storey was added to the original building, and opened on December 1st, 1936. Thus since 1923 the available floor space has been increased from 1,600 sq. ft. to nearly 8,000 sq. ft.

The staff now number more than 40 in comparison with the total of 11 who were employed when the laboratories at Hendon were first occupied. There is now excellent accommodation for conducting fundamental research work and for

carrying out *ad hoc* investigations arising out of queries which are constantly submitted by members.

Research.

The B.L.R.A. at the beginning of its existence commenced investigating each section of laundry processes, in the belief that satisfactory laundering stood for the complete removal of dirt from the articles to be washed with minimum wear of the fabrics. Methods of measuring the colour and of observing the efficiency of cleansing of washed articles were instituted. Research on the washing process, assisted by these methods of measurement, has resulted in the establishment of what is known as the "Graded Wash Process"—a washing process designed to cleanse articles as thoroughly as possible and at the same time to maintain their original strength and colour.

The research work now in progress includes studies of the fundamentals of detergency, i.e., the physical properties of soap and alkaline solutions as well as those of the new detergents known as sulphonated fatty alcohols. It is hoped that this work will lead to a clearer understanding of the particular functions of alkalinity, temperature and the individual soaps, etc., used. The particular needs of wool washing are being investigated by a special enquiry into the behaviour of wool under conditions likely to be met with in washing.

Engineering.

Apart from the research laboratories, there is a well-equipped engineering shop. Here, and in the experimental laundry, the performance and design of laundry plant are studied. Routine work consists of the examination of various plant and apparatus submitted for test by manufacturers. The study of plant performance frequently leads to the suggestion for some advantageous modification or to the design of special apparatus. One of the most striking examples of this advantage is undoubtedly the invention by the B.L.R.A. of the Interrupter Gear. This is a fitting which is attached to a washing machine and provides for the introduction of certain periods of rest during the actual washing process. It is particularly applicable to the washing of woollens and to fragile articles such as damasks and silks. Practical experience has shown that the Interrupter Gear is of great assistance in prolonging the life of goods. The research work at present in progress, includes a study of mixing in washing machines, the investigation of the effect of acceleration on the rate of extraction by hydros and a method of rinsing in the hydro-extractor.

Experimental Laundry.

Fundamental research is nearly always commenced in the laboratory, as many detailed and accurately controlled experiments are generally necessary before the final method of investigation can be selected. It is also obviously cheaper.

In due course the work is transferred to the experimental laundry which is equipped with full size laundry plant. Here the results of research can be tested out and the close proximity to the laboratories themselves ensures that the trials carried out are always scientifically controlled whilst the commercial conditions under which the laundry operates ensure that the practical requirements of any new method will not be overlooked.

Moreover, certain lines of research can be pursued directly in the laundry. The examination of the performance of laundry plant is always in hand. New models and new inventions are often submitted for test by manufacturers and the Association is thus able to keep its members informed upon these matters. New processes can be tried out, new methods of finishing tested and the results of analysis of laundry materials can be amplified by test in the laundry. Although all the preliminary large scale work is carried out in the experimental laundry, trials in the laundries of members of the Association are suggested if it is thought that advantage will thereby be gained.

Analytical and Consulting Department.

In order to be able to advise members on the application of research to their individual requirements it is frequently necessary first to obtain full information as to the composition of all or some of the materials which they use. For this reason alone the equipment of the Analytical Department would have become a necessity. Apart from this however, the research work itself often involves analyses and gradually, as the work of the Association has increased, the services of the Analytical Department, which consists of both chemical and textile laboratories, has become more and more valuable.

Chemical Laboratory.

In this laboratory the analysis of substances used in the laundry can be undertaken. For instance should a member require advice on the softening of his water supply, it is obviously necessary first to know the composition of the water in order that the correct method of treatment may be determined and the examination carried out is therefore arranged to cover all points which may need to be taken into consideration. Alkalies, bleaches, blues, soaps, soap powders, spirit soaps, starches, etc., can also be examined in this laboratory.

The Textile Laboratory.

This department undertakes the examination of damaged and otherwise faulty fabrics, each query being thoroughly investigated and a report of the examination issued. If the results of such an investigation indicate that the fault is due to the use of an unsatisfactory washing process, it is recommended that the process be tested by means of our test piece service. In this way it is possible to ascertain accurately the effect of the process and suggest suitable modifications. On the other hand, if there is indication that the defect is due to a fault of manufacture, communication with the manufacturer concerned is established according to the circumstances, and an effort is made to persuade him either to withdraw the faulty fabric from the market or to replace the article.

The special test pieces mentioned above are also supplied for treatment with any particular classification of work. The examination of the test piece on its return to the laboratory, gives an accurate indication of the effects of that particular process, and it is possible to determine if the member's process is satisfactory, and if not, to suggest such modifications as may be necessary.

More recently the work of the Textile Laboratory has been extended to include " launderability " or " shrinkage " tests on samples of new fabrics. By testing such fabrics under controlled conditions the extent of shrinkage can be determined. The suitability of the fabric to undergo treatment by a normal process or by special treatment is then found. This is a service which is helpful not only to launderers but also to manufacturers and distributors of textiles, many of whom now make a point of submitting samples of new fabrics for launderability tests before they are placed upon the market.

Development work.

Having brought certain pieces of research work to a successful conclusion, and issued the results to members in the form of reports, attempts are made to help members to put these results into practice by sending an experienced member of the staff to their laundries. The Development Officers as they are called, examine and test the processes and methods in use, and their observations and advice are communicated to members both verbally and subsequently in writing. The Development Officer is always ready and anxious to discuss individual problems with the laundry member and can also show, by practical demonstration, how helpful tests can be carried out by the member himself. This development work is a very valuable feature, since it serves to bring the results of the laboratory right into the laundry.

Further, there is the very important co-operation with the Textile Research Associations. Publications are exchanged and problems of mutual interest are

discussed. Joint investigations are also undertaken, such as the work at present in progress in collaboration with the Wool Industries Research Association on the question of wool shrinkage, and also on the fastness of dyed wool to washing. This should show that the British Launderers' Research Association is trying to make laundering a science, as well as an art. A short description of what happens to garments when they reach the modern laundry will now be given.

Modern Laundering.

The garments are first sorted and checked in order to see that every article in the bundle or hamper bears the correct mark. The various articles are then divided into groups, such as sheets, socks, table-linen, wool goods, silks, coloured goods, and so on. For each group there is a particularly specialized washing process. This point cannot be too strongly emphasized. The processes are chosen so as to be suitable for the textile material from which the articles are manufactured and so that they shall be adequate for removing the soiling matter without undue damage to the fabric.

Having been washed, the goods are placed in the perforated cage of a centrifugal hydro-extractor. They are not put through a wringer or mangle. From the hydro-extractor, the goods are taken in a damp condition and are ready for ironing. Flat work, such as sheets, or table-linen passes through large ironing machines termed calenders. These consist of a curved, polished steel bed, heated by steam, and a heated revolving cylinder, covered with felt and sheeting, which just fits the bed and whose weight is supported by bearings at each end. Thus the pressure on the bed can be adjusted to what is necessary to produce a perfectly finished article. In the calender, the equivalent of the ironing board with its blanket and sheeting, moves, whilst the polished steel part, corresponding to the hand-iron, is stationary. Calenders may be fitted with one, two, four, six or eight rollers. Shirts, white coats and the like are finished on specially made steam heated presses, collars are handled in a special department, fine silk articles and finery are hand-ironed. In the finishing department, therefore, each fabric and garment is given the most suitable finishing treatment.

The finished goods are then examined by the packing department, are re-sorted into groups according to the laundry mark, checked against the customer's laundry list, and finally packed into hamper or parcel, ready for delivery.

The Wash House.

It is in the wash-house that the most important parts of the laundering process take place. When talking of commercial laundries people often say, " Oh—I do not send my linen to a laundry—they use chemicals." Of course they use chemicals—and so does every one who uses soap, soda, water, blue and the various washing powders which are on the market. The laundry's chief chemicals are water, soap, and soda. For stained table-linen and the like, sodium hypochlorite is used to remove the stains—but it is used under carefully controlled conditions, which cannot be said of some proprietary products which are available for home use. It is also important to remember that the treatment which a fabric or an article receives during finishing or during its preparation for the market, has an important bearing on its subsequent life, particularly during laundering.

Water, the main raw material, is softened by having the lime salts removed from the town or corporation supply. If goods are washed with soap in hard water, lime soap is deposited in the fibres of the fabric and takes traces of fine soiling matter with it. That is why goods which are washed at home in hard water, gradually go very grey. Here is the first point I want to make therefore, regarding the modern wash-house—soft water is used, and is considered of paramount importance.

The washing processes which have been designed by the Research Association, are based on scientific principles. The following typical white work process for the washing of sheets, is an example of the type of process called the "Graded Wash." The load of sheets is placed inside the washing machine, which consists of an inner, perforated cylinder which revolves inside the outer casing which contains the washing liquid. In this first operation called the breakdown, cold soft water, to which has been added just an ounce or two of soda, is used: the temperature is gradually raised to 90° F., and this first operation serves to wet out the clothes, to remove loose soiling matter and to neutralise any acid soiling matter. The water is then run out of the machine and a fresh charge of clean soft water is run in. To this is added a good soap solution and a little soda. The temperature is gradually raised to 120° F. The control of the temperature prevents the coagulation of albuminous matter before it has been removed from the goods and the good lather which must be present takes away the larger dirt particles in suspension. After 10 minutes, this soapy liquor is run off, a fresh charge of warm soft water is put into the machine and more soap and soda are added in different proportions, the temperature being raised to 140° F.

Again, this soapy liquor is discharged into the drain and hot soft water is run into the machine with soap and soda solutions. This time, the amount of soda present is greater than the amount of soap, and the temperature is raised to the boil. This procedure is necessary in order to remove the yellowish patches which otherwise remain in the centres of sheets, pillow-slips, etc., due to exudations from the body, and also to remove very fine particles of soiling matter which are ingrained in the fibres.

After the boil liquor has been discharged, the load of goods receives four separate rinsings with soft water. The first two rinsings are really hot, at a temperature of 180° F., the third is warm and the last cold. Thus from the foregoing, you will see that the graded wash provides for eight complete changes of soft water, including three washes in soapy solutions.

The process thus outlined is a typical one for white work and is modified to suit different classes of white fabrics. For instance, stained table-linen needs treatment with sodium hypochlorite. This stain removal is carefully controlled. It is carried out in the second wash, in the presence of the soap: the temperature is not allowed to rise above 140° F., and the amount of chlorine from the sodium hypochlorite, is never allowed to exceed 5 grains per gallon. By this means, undue attack on the cellulose is obviated.

Print shirts are treated slightly differently. They are not actually boiled, the temperature not being raised above 190° F., and the alkalinity of the soap liquor is kept lower: but to assist removal of the dirt ingrained at the neckband and the cuffs, a sulphonated fatty alcohol is used with the soap. This has absolutely no effect on the textile fibres, but is an excellent penetrating agent and so assists the soap in removing the dirt. Used by itself, it does not suspend soiling matter as adequately as soap. The use of these sulphonated products does away with the necessity for scrubbing the neckbands, and cuffs.

Coloured goods are divided into several classes. Sometimes dyes are so loose that they will run in cold soft water, and it is sometimes necessary for the launderer to immerse such loosely-dyed articles in a solution of common salt, and to wash them therein using a sulphonated fatty alcohol only, as the detergent.

Coloured bordered table linen is not bleached with sodium hypochlorite, but with sodium perborate, using only 2 to 6 ounces for every 100 lbs. dry weight of tablecloths. The use of perborate in this instance is based on scientific principles. The type of colour used for dyeing the yarns forming the coloured borders is a vat dye. When there is a trace of a reducing agent present in the boil liquor, such for instance as a trace of old starch, then the vat dye becomes reduced, and in this condition, is soluble, and tends to mark off on to the undyed portions

of the tablecloth. The presence of sodium perborate not only removes tea and coffee stains, but prevents the reduction of the vat dye and so keeps it in its insoluble condition.

Different problems arise with woollen goods owing to the nature of the wool itself. Wool naturally tends to felt unless it has received treatment to render it "unshrinkable." To minimise felting, the launderer gives wool goods as gentle a process as possible, consistent with adequate cleansing. Thus the temperature of the washing liquor is never raised above 100° F., and mechanical action is cut down to a minimum. This can be done by fitting a B.L.R.A. interrupter gear to the washing machine. When this gear is in operation, the machine will rotate for 15 seconds and rest for 75 seconds, with the goods immersed in the detergent solution. Soiled woollens are given two washes, one of 10 minutes and one of 6 minutes, and the washes are followed by 2 or 3 rinses, also with the motion interrupted. Goods made from untreated wool will tend to felt under any washing conditions, if they are at all soiled, because when they are hand-washed, some rubbing is generally necessary, and this in itself will cause felting.

The other difficulty with which the launderer has to contend is loss of stretch on wetting out, due to an excessive amount of "boarding-out" during manufacture. In this case, too, the launderer is generally blamed for having "shrunk" the garments, whereas he cannot be held responsible for diminution in size in this connection, provided he has used a satisfactory woollen washing process.

In linen and cotton goods, the shrinkage problem is different. The shrinkage which often occurs in linen or cotton goods is directly due to recovery of the material from the stretching which has taken place during manufacture.

Damages which occur during laundering can be attributed to three causes :—

(1) Faults in the laundering process.
(2) Faults in manufacture.
(3) Misuse or accident during wear or use.

The various types of fault are frequently brought to the notice of our fabrics department. The reports, which are issued to members, are quite impartial and unbiassed, and if the fault in the article has developed as a result of incorrect laundering treatment, the blame is placed on the launderer.

For determining whether or not a laundering process is at fault, special test pieces of fabric, tarantulle, wool, striped shirting, etc., of known characteristics are used. An appropriate test piece is sent to the member's laundry, where it is washed 20 times with loads of goods. After the 20th wash, the test piece is returned to the laboratory and examined for chemical damage, loss of cotton material, loss of colour, loading, etc., etc., and from the analytical results, it can be determined just in what way the process falls short of the ideal.

In the course of the lecture slides illustrating the types of fault that are encountered in laundering work were shown.

Yorkshire Section

CONSIDERATIONS AFFECTING THE DESIGN AND CONSTRUCTION OF FABRICS FOR LADIES' WEAR

By T. Bellwood, A.T.I.

A paper given to the Yorkshire Section of the Textile Institute on Jan. 28th, 1937, at the Midland Hotel, Bradford.

Few people realise, when looking at the displays of fashionable fabrics, how many factors enter into the design and construction of the cloths. It is the object of this short paper to review some of the considerations which the designer and producer must bear in mind.

The influence of national events is almost too obvious to need comment. After the death of the late King George V there was a big demand for fabrics

in black, grey and other sombre shades. Designers were provided with plenty of scope for tasteful fabrics in black and grey, and grey and mauve shades. The Coronation has produced extensive demands for special fabrics in the colours of the national flag and designers have been busy with patterns incorporating red, white and blue and tones derived from them.

The weather and its vagaries influence fabric design to a marked extent. The light weight fabrics demanded in the recent warm summers have had to give place to the heavier cloths more serviceable in the average wetter and cooler seasons.

The expensive designs emanating from the Paris Salons exercise an influence upon the design of far cheaper lines. Frequently these exclusive cloths incorporate ideas which, though produced in an entirely different way, are very effective in the cheaper ranges of cloths. A good example was provided a few seasons ago. A Paris fashion house produced a design embodying beads stitched on to the cloth at regular intervals. The idea suggested to a clever designer the possibility of producing the effect in another way. Warp or weft threads were floated in a pre-determined way. They were cut before the scouring and subsequent processes, during which the loose ends rolled up and felted into the bead-like formation.

Other influences upon the design of fabrics which have their fleeting hour of popularity may be traced to the moving pictures and the artistes who star in them. These examples of factors which influence design are perhaps sufficient to show that the cloth constructor who would have his creations enjoy popularity must be quick to perceive the direct and indirect bearings of events of all types upon fabric design.

So far the factors dealt with have been of relatively minor significance or else their influence has been exerted over a short period only. The prices of raw materials exert a greater and more permanent effect on design. It must be admitted that the price is a factor of predominating importance, for it has a highly restrictive effect in every respect. The prices of raw materials have been rising for some time. This movement brings in its train a very varied assortment of problems for both designer and producer. Whatever ideas the designer may have and whatever novelties in design, colour or finish he may be able to introduce, the fact remains that the prices of the raw materials are the governing factors and that they alone practically decide at what figure a cloth can be sold.

The desire for change is one of the fundamental elements in the subject of fashion. When crisp, rough handling fabrics have had a run of popularity there is usually a reaction in favour of smooth supple cloths. In rough fabrics the coarser types of wool can be employed with advantage, but for smooth face finished cloths the finer grades of wool are essential. An example is thus provided of influencing factors coming into opposition and even nullifying one another. The rising prices of raw materials are putting difficulties in the path of the designer striving to provide the face cloths of smooth handle for which the demand has appeared. The cloths of rough appearance may therefore enjoy a partially continued popularity because the smooth ones cannot be produced at competitive prices.

It is interesting to consider the position of the designer and manufacturer beginning the construction of new ranges of patterns, say for the winter season. The discussion will proceed mainly from the point of view of the producer of woollen fabrics suitable for mantlings, etc. Consideration must first be given to the prices at which various customers have placed substantial orders in the immediate past. A very broad review of the changes in prices of the raw materials will determine at once whether it is possible to accept orders at these old prices or not, and in the latter case, what increases are inevitable. Having thus roughly settled the prices at which it is thought the cloths can be sold,

the blends are planned and the costs of specimen blends are worked out. This process is a more comprehensive one than is usually realized because woollen fabrics frequently incorporate mohair, cashmere and other hairs, feathers, and synthetic filaments. These are then considered with regard to the standard ranges of the producing firm, cloths which are made every season and differ only slightly in design. In many cases, in order to produce the fabrics at the prices ruling in a previous season, thicker yarns of lower quality fibre would have to be used. If the weights were to be kept the same, the setting would have to be altered and the designs would automatically become unsuitable for relatively loose cloths of spongy handle would result instead of fabrics of firm solid handle.

At this stage a number of new factors would have to be taken into account. The substitution of a lower quality of wool for a fine one would, in many cases, preclude the application of the same type of finish. In fact it results virtually in a cloth of entirely different character, demanding totally different treatment. Sometimes, if dark shades were required, it is possible to use dark coloured mungo or shoddy, which are cheaper than the same qualities in light shades. Further examples of such factors could easily be found.

For mixture yarns the component shades must be decided in order that the materials may be dyed preparatory to the putting down of the blend. It is impossible to define what constitutes an ideal range of shades for any fabric, since no two persons' ideas coincide. Black, various shades of grey, and " naturals " can generally be safely included in every range of mixture yarns for ladies' fabrics. In determining colour effects a balance round the base hue or colour appears to be necessary. Fancy yarns find wide application in the construction of woollen fabrics. The large variety of fibres now available makes possible a most extensive range of fancy yarns, both for piece dyed and for mixture fabrics.

When the yarns have been produced the next step is the designing of the cloths. Like the price of the raw materials the designing is a factor of major importance and one with which it is difficult to deal in general terms. Excessive ornamentation is quite as serious an error as undue plainness. If the fibre is to be the effective element in a cloth, the design should be the vehicle to display the fibre. In an emphatic design, yarns of strong character create harsh contrast. The experienced designer knows that certain weaves are frequently used and are always popular and he will make use of one or more from this class in every range. As with the handle of cloth there is usually a reaction in favour of neat small all-over effects after large well marked patterns have been the vogue. Design is very closely interwoven with finish and the type of finish which is to be fashionable will exert no small effect upon the designs. It is also intimately connected with the materials of which the yarns are composed.

Further instances of the bearings of different factors are provided by the consideration of a few designs for a velour finished fabric. One of the yarns in the quality employed may contain fibro or viscose staple fibre. Made up in plain weave, broken twill or other similar design, dependent to some extent on the counts of the yarn, the fabric when finished will not possess any pronounced weave effect. Its appeal will rather be due to the synthetic fibre element, which does not take the dyestuffs when the fabric is piece dyed. In such constructions the weave is a constructive rather than a decorative element. Plain diagonal or neat rib style may be similarly used. Yarns containing feathers or mohair may be used in like fashion, the actual design of the cloth being used as an unobstrusive background against which to display the effect fibres.

Styles for tweeds would naturally be different in character from those suitable for velours. It may be decided to incorporate a knop yarn overcheck with a herringbone design, the colour of the checking for each ground shade being chosen so as to preserve a balance of contrast in colour and tone. A range could be built up using knop, slub and gimp yarns in all over effects.

This part of the subject could be extended indefinitely. In these ways series of patterns from which customers may choose are brought into being.

Popular types of cloth sometimes entail difficult problems for the designer and tax the mill equipment to the utmost. An example is provided by cloths of open setting in which thick yarns with low twist are employed. Very careful attention must be given to the weave in order that the cloth may have the requisite strength. The limitations of the looms as regards figuring capacity are thus frequently emphasized. Automatic looms may also impose restrictions in cloth construction.

With the operations of dyeing and finishing it may be thought that the work of the designer and the producer of fabrics is completed. Generally this is so but it is not always the case if ranges of new seasons' patterns form the work in hand. Frequently the merchant would prefer a given pattern in a different colour or with a finish of different type.

A subject such as this could easily be treated in a long series of papers far more adequately and completely than in a single short one. Yet enough may have been written to show how numerous are the factors which must be considered. In addition they interact in a complicated way and it may be said that there is not one single process in the long chain which may not modify radically the character of the cloth.

Midland Section

DEVELOPMENTS IN THE KNITTING INDUSTRY

By W. E. BOSWELL, F.T.I.

Abstract of lecture given at University College, Nottingham, to the Midland Section of the Textile Institute, on March 11th.

Mr. Boswell observed that developments have taken place in every phase of the industry. The spinner has evolved new yarns, and better methods of winding have been thought out. The builder of knitting machines has made the machines more productive and adaptable. Many machines have been re-designed in the light of past experience and new methods of oiling and the enclosing of many parts have made them easier to maintain.

Some of these developments may be considered in brief detail. Wool yarns have not shown many changes, though the fancy variety, such as knop and slub have been used in greater quantities for outerwear fabrics. Wool yarns with a silk fleck are being worked at present for men's pull-overs, ladies' coats, etc. Twistless rayon yarns are being used in the warp knitting trade. Some of these are really twistless, and care must be taken to control ballooning in the warping operations. Others have a small amount of twist to allow them to be warped more easily. These twistless rayon yarns also work well on the bearded needle circular machines, the fabrics having a very full handle.

Staple fibre rayon yarns are being used in increasing quantities, an admixture of 50 per cent. wool, good quality wool for outerwear, cross-bred wool for foot-wear, proving very popular. Counts of this type of yarn are available up to 40's cotton size. Staple fibre rayon and cotton yarns are used for underwear fabrics, a popular mixture having 75 per cent. or 80 per cent. rayon. Viscose staple fibre twisted with an acetate continuous filament yarn is used in the warp trade to obtain a mixture stripe. When used with stripes of solid viscose alternating with stripes of acetate this gives very nice effects.

Coarse filament denier staple fibre yarns are suitable for use on circular rib jacquard machines for pull-overs, etc., this yarn giving a fabric of good appearance without the weight associated with the heavier continuous filament yarns.

Rubber yarns have not increased in use to any large extent. A new yarn made by spinning latex and viscose solution together is available and it is claimed that this yarn is very regular and has a long life.

Winding

Developments in this direction give increased speed of winding. Attention has been given to the building of the yarn on the bottle bobbin to give an improved off-wind. The bobbins on some of the new machines are arranged horizontally, and the bobbins are held by bearings at each end, spindles being dispensed with. The bearings are movable on slides to take different sizes of bobbins. The new cone winding machines show revolutionary changes, the use of the rotary traverse roll drive for the cone eliminates the use of thread-guides and cams, reducing noise, and building cones of uniform density with the minimum amount of chafing on the yarn. Tensions and slub-catchers are self threading. Enclosed mechanism and centralized oiling reduce maintenance time and costs considerably. The fact that the winding machine builder is alive to the requirements of the manufacturer is shown by the efforts made to provide new packages designed to prevent the trapping of silk and rayon during the knitting processes.

Knitting Machines

Single unit machines for fashioned footwear in fine gauges make the stocking in one piece, and will probably very largely replace the method at present used where two machines, a legger and a footer are required to make a stocking. The French type of foot is made on the single unit machine, and many of the improvements thought out for this machine are being incorporated in the machines using the two machine method. Improvements on fashioned hose machines include an anti-rebound mechanism, rollers on cams, ball bearings, shorter needles with consequent reduced movements on the levers, hooked knocking-over bits to reduce the risk of loading-up on the needles, and improved welt bars where the needle head can bury itself in a trick so that touch will tell when the points are covering correctly. Safe knitting speeds are from 75 to 80 courses per minute on a 15-inch head machine. It is gratifying to note that the British builders of this type of machine are keeping pace with these developments. A few of the features of their machines are ten thread carriers with the attachment for making the three carrier work required on pure silk hose, splicing carriers that can be racked over either one or two needle spaces when making spliced ankle and foot and easy access to all working parts.

Seamless Hose

Gauges in these hose keep pace with those of the fashioned variety, 340 and 360 needles in a 3½-inch diameter cylinder corresponding to the popular 42 and 45 gauge fashioned hose. The needles are made with finer hooks to allow a small stitch to be made. Attachments, added to cope with the changing fashions, are disappearing in favour of pattern drums, controlling the needles through the medium of jacks, for the making of the patterned spliced ankle and foot, fish-net clocking, or all-over fish-net effects. Other features are square heels, to resemble the heel of the fashioned hose, gusset toes, giving more room in the toe, mock seams and mock fashion marks.

Ribbed hose and half-hose machines of the double cylinder type have been made more versatile, important developments including provision for the making of slack welts, two feed machines to increase production, five colour striping, plating patterns, draw threads to separate hose without cutting, rubber feeding for the rib-top, and true jacquard patterns in colour. The patterning capacity of the machines for the manufacture of the embroidered half-hose has been increased, and horizontal stripes can now be made along with the vertical elements of the design obtained by embroidery.

Warp Knitting

Knitting speeds have increased as the machine builders have adopted modern methods by using a shorter needle and inclining the needle to the presser, thus shortening the knitting movements. Modern speeds are 450 courses per minute on the narrow, and 350 on the wide looms.

More attention is being given to the use of three bars of threads and this, together with the use of a cut presser bar, gives a large range of fancy fabrics. A new feature is a tuck presser bar in small sections, enabling sections to be screwed on to a solid bar to give many combinations.

Sectional warping is being developed, and manufacturers are cautiously trying out this method which is certainly much quicker than the old one.

Direct warping is from creel to beam with stop motions for any broken ends. Counters show the length on the beam, and automatically stop the machine when a set length has been warped.

Circular Latch Needle Machines

New cam systems are in use on this type of machine. Simple alterations will allow either fish-net, float, tuck, or laid-in work to be made.

Patterning systems have been improved and pattern wheels are successful on machines as fine as 28 needles per inch. Rib patterning machines are improved, the making of garment lengths with rib border and draw-thread bringing the product of these machines nearer to that of the flat machine.

Larger pattern drums, more butts on the pattern jacks, and two-way racking of the drums increase the patterning scope tremendously. Selective transfer of the cylinder stitch to the dial needle gives garments with rib and plain stitch effects combined with open-work or lace stitch patterns.

Heavy tuck stitch fabrics, with the tucking on the cylinder needles, have been very popular both for underwear and outer-wear. Four feeder machines are being used for these, the needles tucking on three feeders and clearing on the fourth.

Flat-Knitting Machines

Double and treble cam systems have been further improved. Selective transfer of stitch can be made from one needle bed to the other, and new cam systems give tuck, laid-in, and other effects on one garment. Interchangeable needle beds, 4½ to 10 gauge, solve the problem of the manufacturer requiring several gauges of fabric from a small plant of machines. Improved cam systems on flat pearl machines allowing roll and French welts, circular work and tuck stitches, give these machines much greater scope for original design.

Making-up

Increased speeds of stitching machines are achieved in this department due mainly to new designing, lighter parts more easily balanced, semi-automatic lubrication, shorter movements of the needle and loop forming parts. Old systems of lubrication by hand are being superseded by sump and wick method. Speeds of some overlock machines have been increased from 3,000 to 4,500, double chain-stitch flat bed machines from 3,200 to 4,300 stitches per minute. Speed of stitching must not be above the manageable limit of the operator; the high speeds serve for small stitch work and short bursts, but are not suitable for large stitch work.

Design

Fabric and garment designers are now indispensable to manufacturers, and people are being trained in the technical work relating to the knitting machine so that they understand stitch structure and the possibilities of the various types of machines.

Annual Meetings

Yorkshire Section

The Annual Meeting of the Section was held at the Midland Hotel, Bradford, on Thursday, 6th May, 1937, at 7.30 p.m. The Minutes of the previous meeting (23rd April, 1936) were read, approved, and signed.

The Chairman, Mr. G. Haigh, Bradford, briefly referred to the Papers delivered at various Section meetings throughout the past session, and expressed regret that attendance had not been greater. He reported that Mr. B. Musgrave had been appointed to represent the Section on the Federation of Textile Societies and Kindred Organisations, and asked for confirmation of this action. He urged upon Members the desirability of familiarising themselves with the facilities offered at Headquarters, and expressed his thanks to the Honorary Secretary and to officials of the Institute for help rendered him during his year of office.

The General Secretary read the names of the Committee whose term of office expired at this meeting, and who were eligible for re-election. He also intimated that a letter of resignation had been received from Mr. S. Saville. On the proposal of Mr. J. R. Emms, seconded by Mr. H. Binns, it was decided to recommend the following names to Council for appointment as the Section Committee :—A. Bailey, H. Binns, J. Dumville, J. R. Emms, G. Haigh, H. Haigh, J. R. Healey, N. C. Gee, E. T. Holdsworth, F. Kendall, S. Kershaw, W. Morley, H. Richardson, T. H. Robinson, W. S. Stansfield, E. A. Swift, D. Wilson.

The following officers were appointed for the ensuing year :—G. Haigh, Chairman ; E. T. Holdsworth, Vice-Chairman ; W. Garner, Hon. Secretary.

A unanimous vote of thanks to the Officers for their services during the past year was also recorded.

It was decided to leave the question of the appointment of the Emergency Committee to the discretion of the Section Committee.

It was also decided to circularise members of the Section with a view to ascertaining which was a suitable night for meetings, and whether any interest was shown in holding meetings outside Bradford.

London Section

The Fifteenth Annual Meeting of the London Section, held at the Hotel Victoria, Northumberland Avenue, London, W.C.2., at 6.30 p.m. on Wednesday, 28th April, 1937. The Minutes of the last Annual Meeting (2nd September, 1936) were read, approved and signed. The Committee's Report to Members of the Section for the past year was adopted.

The Hon. Secretary, Mr. A. R. Down, reported that nineteen nominations had been received. On the proposition of Mr. Carter, seconded by Mr. Scott, it was unanimously resolved to recommend the following to Council for election as the London Section Committee for 1937 :—Messrs. A. B. Ball, G. M. Canham, C. H. Colton, A. R. Down, A. E. Garrett, A. Gowie, F. C. Harwood, F. Henley, J. Howard, I.S.O., L. S. Irvine, A. Mason, W. H. Matthews, R. S. Meredith, P. J. Neate, T. C. Petrie, B. D. Porritt, G. A. Rushton, C. F. Sunderland, and A. Wigglesworth.

It was learned with considerable regret that owing to ill-health, Mr. L. J. Mills had decided not to seek re-election. The Hon. Secretary was requested to convey to Mr. Mills the meeting's regrets and also to express its keen appreciation of the many years of valuable service he had given so freely to the Section.

Pleasure was expressed that the Section expected to be able to revert to the full programme of Lectures, etc., for the next session. Satisfaction was also recorded that it was hoped to again issue the card giving the Section's activities for the coming session. It was felt that the cards were very good propaganda for the Institute. The syllabus was discussed at length and the Hon. Secretary was requested to bring the suggested subjects to the notice of the Lecture Sub-Committee.

The Chairman of the Section, Mr. T. C. Petrie, was heartily thanked for his unstinted efforts on behalf of the Institute in general and this Section in particular. The Hon. Secretary was also requested to convey the best thanks of the meeting to the Council of the Drapers' Chamber of Trade of Great Britain and Ireland, for their continued interest and great support, making special reference to the hospitality extended during the last Annual Conference of the Institute in London.

Midland Section

The Annual Meeting was held at Kings Head Hotel, Loughborough, on 7th May, 1937. Dr. E. Wildt presided over a small but very representative attendance. The Minutes of previous Annual Meeting were read and approved.

The Hon. Secretary, Mr. T. A. Purt, presented his Annual Report and stated that the Membership of the Section as at the 1st May, stood at 142, including 39 Associates and 8 Fellows. The following have been made Associates since the Last Annual Meeting :—G. Clarke, R. S. Harrison, H. B. Hopewell and M. F. Ward, while Dr. E. Wildt had been elected a Fellow.

For the first time since the inauguration of the Midlands Section, an increase in the Membership was not shown, but a number of Members had been transferred to other sections, otherwise there would have been a slight increase over last year.

The programme as originally arranged for the previous session was carried out in its entirety with the exception of the suggested Paper by Mr. H. A. Smith, on Modern Methods of Making Up. It was impossible to secure his services and a lecture by Mr. W. Hardacre, A.T.I. was arranged instead.

The Season was opened by a visit to the Leicester Textile Machinery, Accessories and Fabrics Exhibition, when we had the pleasure of a most interesting Paper by Mr. Frank Nasmith, F.T.I., the Hon. Secretary of the Institute.

The November visit to the L.M. & S. Research Dept. at Derby was a great success and very well attended. Gratitude was expressed to Mr. W. Pritchard and his assistants, for the excellent arrangements made on this occasion.

The Visit to Gerards Soap Works in December was most interesting and it was regretted that the attendance was so small but this was doubtless due to the inclement weather.

On December 11th the first Annual Dinner was held at Nottingham and considering the shortness of the notice given, this was carried off most successfully. The President, Mr. Turner, presided ; Mr. Frank Nasmith, the Hon. Sec., Mr. E. A. Swift (of the Yorkshire Section), and Mr. H. L. Robinson also attended. It was unanimously agreed to make this an Annual fixture with the date arranged at the beginning of the season and printed on the Programme.

Mr. W. Hardacre gave a very interesting paper in January, at Leicester, on " Developments in Fibro and Wool Yarns," to a well attended meeting, while in February a party of over 50 visited the British Bemberg Works at Doncaster. This was a record attendance for any Midlands Section Meeting.

Mr. Boswell's paper in March was a very fitting climax to a most successful season as he dealt very ably with his difficult subject, " Developments in the Knitting Industry," demonstrating his various points with an excellent display of samples.

At a Committee Meeting held in November it was unanimously decided to recommend Dr. Wildt's name to Council as Chairman of the Section Committee, which recommendation met with full approval.

The Hon. Secretary stated that Dr. Wildt had carried out the Chairmanship in a very efficient manner, and in addition to this office he spoke of the good work Dr. Wildt was doing on the Council, the Selection Committee and the Fabrics Competition Committee. Congratulations were extended on his election to Fellowship and also on his re-election to Council.

Thanks were extended to Mr. Chamberlain and other members of the Committee for the very valuable services rendered during the past season.

Although the existing Committee was considered rather large, it was decided that in view of the widely scattered section it was advisable to retain all the members, and it was agreed to recommend to Council that the Committee be re-elected *en bloc* with the inclusion of Mr. A. S. Greenwood, who had previously served on the Scottish Committee and was now resident in the Midlands.

Mr. T. A. Purt was re-elected Hon. Secretary and he was warmly thanked for his previous services.

Suggestions were made and discussed for the Programme for the coming session. It was decided that the second Annual Dinner be held in Nottingham, on Friday, December 10th, while final arrangement of other fixtures was referred to Committee.

Dr. Wildt welcomed Mr. W. Howarth to the meeting in his capacity of Member of the Council and Chairman of the Institute Development Committee, to which Mr. Howarth suitably responded.

The meeting concluded with a hearty vote of thanks to the Chairman, which was proposed by Mr. W. Howarth and seconded by Mr. A. S. Greenwood.

Scottish Section

The Annual Meeting of the Section was held in the North British Station Hotel, Edinburgh, on Saturday, 17th April, 1937, at 6 p.m., when Dr. A. W. Stevenson presided over a representative attendance of Members, including Mr. H. L. Robinson, General Secretary of the Institute.

After intimating apologies for absence, the Hon. Secretary read the Minutes of the previous Annual Meeting as printed in the *Journal* and already circulated to all members of the Section.

The Hon. Secretary then submitted a report of membership at 28th February, there being 87 Members, a decrease of one on the previous year. The distribution of membership remained very much the same as usual. There was also submitted a short financial statement, showing total expenditure of £7 10s. 2d., being at the rate of 1/8¾ per Member.

The Chairman reviewed the past session and referred to the fact that only one separate meeting of the Section was held, viz., at Galashiels on 26th March, 1936, when Mr. W. Wilkinson (Blackburn) gave an Address entitled : " Weaving Mechanism," illustrated by cinema film. On the afternoon of the same day, a visit was paid to the Works of Messrs. Gibson & Lumgair, at Selkirk, and the Committee took the opportunity of expressing appreciation of the facilities granted by that firm. There was also a public meeting at the Heriot-Watt College, Edinburgh, on 12th February, 1937, to which the attention of Members was officially drawn at that time, the subject being, " Air Conditioning in Industry." Three meetings of the Committee were held during the session, and the Chairman and Hon. Secretary had a meeting with officials of the Scottish Section of the Society of Dyers and Colourists on the subject of a Joint Conference with that body. In addition, through the Hon. Secretary and Members in Carlisle, interest has been maintained in the recently-formed Cumberland Textile Society. Arrangements had been made for a one-day Conference at Stirling on 22nd May, 1936, but owing to the poor response, this project had to be cancelled almost at the last minute.

The Chairman referred to the retirement of Mr. Athey, and said they were delighted to welcome his successor, Mr. Robinson, who was already well-known to Members in his previous capacity as Editor of the *Journal*. Mr. Robinson addressed the meeting, and mentioned the circumstances under which Mr. Athey had been obliged to relinquish his active work on behalf of the Institute. He also referred to the policy of Council in connection with the more important subjects under review.

The following Members were recommended to Council for election as Section Committee :—Messrs. J. P. Beveridge (Dunfermline), J. C. Campbell (Galashiels), W. Lockhart (Kirkcaldy), S. M. Roberts (Selkirk), A. W. Stevenson (Galashiels), W. Watson (Glasgow), W. H. Wilkinson (Edinburgh), and A. W. Blair (Glasgow).

The Hon. Secretary drew attention to the fact that Mr. H. B. Taylor, Secretary of the Cumberland Textile Society, was present at the meeting, and Mr. Taylor took the opportunity of referring to the work of that Society and to the success which it had achieved during the short time of its existence. A vote of thanks to the Hon. Secretary for his work during the session was accorded on the motion of Mr. J. P. Beveridge, and this terminated the proceedings.

Following the Annual Meeting recorded above, a further meeting was held at 7.30 p.m., when Mr. G. F. Sedgwick, H.M. Inspector of Factories, gave an Address dealing with " Accident Prevention," making particular reference to textile factories. Mr. Sedgwick, who was accompanied by two Assistant Inspectors, also dealt with the changes proposed in the new Factory Bill, and his remarks were followed with keen interest. The meeting was then thrown open for discussion, and after the Lecturer had replied to the various points raised, a hearty vote of thanks was accorded on the motion of Mr. W. H. Wilkinson.

Irish Section

The Eleventh Annual Meeting of the Irish Section was held at the College of Technology, Belfast, on Friday, 23rd April, 1937. Professor F. Bradbury was voted to the Chair.

The Minutes of the Tenth Annual Meeting (23rd June, 1936) were read, passed and signed.

The Hon. Secretary, in presenting his report, stated that during the Session, two meetings had been held, at which papers were contributed as follows :—

10th December, 1936 : " Some Effects of Warp Tension during Weaving," by H. Boffey, B.Sc.

18th March, 1937 : " Co-operation between the Textile and Laundry Industries," by F. Courtney Harwood, B.Sc., F.I.C., M.I.Chem.E.

The papers contributed were much appreciated, and there was a good attendance at each meeting. Mr. H. L. Robinson (General Secretary) and Mr. Kendall (Yorkshire Section) were in attendance at the March Meeting.

The Section Membership now stood at 36 as against 34 at last Annual Meeting.

It was decided that the Committee, etc., be recommended to Council for re-election as follows :—*Chairman*, Mr. W. H. Webb (Randalstown) ; *Hon. Secretary*, Mr. F. J. W. Shannon ; and *Committee*, Dr. W. H. Gibson, Professor Bradbury, Messrs. W. J. Cowden, J. Kirkwood and G. R. Beatty.

A discussion took place regarding Meetings for next Session, and it was decided to leave over arrangements so that enquiries might be made regarding suitable lectures.

NOTES AND ANNOUNCEMENTS

Annual Conference at Southport.

There would seem to be general agreement that the subject chosen for discussion at Southport was timely and of definite importance. Any anticipatory trepidation as to the initial stages of the discussion was soon dispelled. Thanks to the Chairman's efforts on Thursday morning and those of the introductory speaker, no lag in the proceedings occurred and a total of over twenty speakers during the first session was evidence of the interest aroused. The ball thus set rolling was helped onwards by the efforts of the Chairman and introductory speaker on the Friday morning. On this occasion over thirty speakers took part in the debate which only terminated with the advent of lunch-time. As perhaps time was not available for all who wished to speak, members are reminded that

contributions may be made in writing, and will be included in the final report of the Discussions, which will appear in full in the July issue.

Meetings of other Organisations.

Attention is drawn to the undermentioned events in the belief that members of the Institute will be interested.

The Fifty-sixth Annual Meeting of the Society of Chemical Industry will be held in Harrogate from July 5th to 9th inclusive. Questions ranging from the problems of alloy cast-irons to the utilisation of waste fruit will be discussed. Mr. A. Charley, of the Long Ashton Research Station, near Bristol, who has recently carried out pioneer research on the use of surplus fruit to make wines, spirits and liqueurs, will open a symposium on fruit juices. He will be followed by Mr. T. N. Morris, of the Low Temperature Research Station at Cambridge, who is concerned with the concentration of juices by freezing, and Mr. J. Arthur Reavell, will speak from the point of view of the chemical engineer. Dr. A. B. Everest will give latest information on the special properties of the new class of alloy cast-irons as material for chemical plant. The Society's presidential address will be delivered by Lord Leverhulme. An attractive programme of excursions covers such varied industries as cocoa and chocolate manufacture, oil and cake mills, clothing manufacture, and the making of solid drawn metal tubes. A visit has also been arranged to the Board of Green-keeping Research at Bingley, the research station of the British Golf Unions Advisory Council. A comprehensive series of experiments will be shown, dealing among other subjects, with the effects of worms, weeds and fertilisers. Full particulars regarding the Meeting may be obtained from Dr. A. L. Roberts, The University, Leeds.

The Seventh International Management Congress will be held next year (September, 1938), in Washington, D.C. Preparation for this event in Great Britain is in the hands of the British Management Council, upon which this Institute is represented by its Hon. Secretary, Mr. Frank Nasmith. It may be that members who will visit the States next year will like to take part in this event. In such instances, fuller information may be obtained from the Secretary, British Management Council, Armour House, St Martins-le-Grand, London, E.C.1.

TEXTILE INSTITUTE DIPLOMAS

Elections to Associateship have been completed as follows since the appearance of the previous list (May issue of this *Journal*) :—

ASSOCIATESHIP

CHARNOCK, Frederick Clement (Southport).
DANZIGER, Georg (Riga, Latvia).
DOWLING, Gilbert (Cawnpore, India).
DUNCAN, John Johnstone (Long Eaton, Notts.).

ASSOCIATESHIP OF THE TEXTILE INSTITUTE

Examination: Part I (Auxiliary Subjects)
Part II (General Textile Technology)

EXPLANATORY NOTES

For the information of textile students and others, the following notes in reference to the above-named Examination and to the requirements for election to the Associateship of the Institute are issued by the Diplomas Committee :—

(1) The requirements for election to the Associateship are set forth in printed Regulations, copies of which may be obtained on application to the Institute. The Regulations should be carefully studied by prospective applicants.

(2) Application for the Associateship (A.T.I.) is restricted to Members (Junior or Ordinary) of the Textile Institute of at least six months' standing at the time of the application.

(3) Institute Members applying for the Associateship must do so on the special Form provided and the application must be accompanied by a Registration Fee of 10/6, which amount is deducted from the Entrance Fee of Two Guineas on admission to the Associateship but is not returned in the event of unsuccessful application. On the Application Form, the statement of qualifications should be presented completely under the respective sections.

(4) The qualifications of each candidate for the award of the Associateship are considered in relation to the requirements set forth in the printed Regulations, and applications may be dealt with as follows :—

(*a*) Applicant exempted from Examination and recommended for election to Associateship ;

(*b*) Applicant referred to Examination, Part II (General Textile Technology) and exempted from Part I (Auxiliary Subjects) ;

(*c*) Applicant referred to Examination, Part I (Auxiliary Subjects) and Part II (General Textile Technology) ;

(*d*) Application declined.

(5) The Institute's Examination is not an examination the passing of which, in itself, secures admission to the Associateship. No person may sit for the Institute's Examination until his application for the Associateship has been considered by the Diplomas Committee and, as a result, he has been definitely referred to Examination.

(6) If referred to Part I and Part II, the applicant must pass both parts in order to complete the examination requirements. The applicant may take the complete Examination in one and the same year on the appointed dates in the month of May ; or, he may take each part separately in different years. In either case, a candidate will not be certified as having passed Part II until he has passed Part I.

(7) Applicants who have so far fulfilled the requirements of the Regulations as to be deemed worthy of reference to the Examination but have not yet complied with the requirements as to occupational experience and/or age (see Clauses 2 and 10 of the Regulations) may be referred to the Examination. Nevertheless, such applicants will be required to complete the qualifications before award of the Associateship can be granted.

(8) *Students in Technical Institutions should consult the Principal or the Head of the Textile Department before proceeding with an application.*

THE TEXTILE INSTITUTE

EXAMINATION PART II. GENERAL TEXTILE TECHNOLOGY

SECTIONS I AND V OF SYLLABUS

10 *a.m. to* 1 *p.m.—26th May*, 1937.

Candidates to answer THREE Questions in each Section

Section I—Fibres and their Production

(1) List, in the order of their importance, the chief wool producing countries of the world. Describe the characteristics of the chief trade types of British and foreign wools with reference to their industrial uses.

(2) Describe, by reference to the appearance under the microscope of a cross-section of a flax plant, the purposes of retting and scutching. Describe briefly how these operations are carried out ?

(3) Write a short essay on rayon staple fibre. Discuss the qualities of staple fibre which are important in its use in substituting or in mixing with other fibres.

(4) Describe the growth and structure of the cotton seed hair. Discuss the nature and consequences of immaturity in raw cotton.

Section V—Analysis and Testing of Raw Materials, Yarns and Fabrics

(1) You are asked to examine a dyed cotton curtain which shows considerable tendering after a long use. Give the possible causes of such tendering, and describe how you would ascertain which was responsible for the damage.

(2) How would you proceed to find the cause of an abrupt change of shade (*a*) in a dyed stocking knitted with gassed yarn ? (*b*) in a dyed stocking knitted with gassed and mercerised yarn? Both yarns are a 100 per cent. cotton.

(3) What is meant by testing in controlled atmospheric conditions ? What are the advantages and disadvantages of this method of testing ?

(4) Describe methods of testing yarns for (*a*) count, (*b*) twist, (*c*) strength, and (*d*) elongation.

SECTIONS II, III AND IV OF SYLLABUS

2.30 *p.m. to* 5.30 *p.m.—26th May*, 1937.

Candidates to answer TWO Questions from each Section

Section II—Conversion of Fibres into Finished Yarns

(1) Ring spinning is to a greater or less extent replacing mule spinning for cotton and woollen yarns. Discuss this tendency in each case from the point of view of (*a*) economy of production, and (*b*) the character of the yarn produced.

(2) Write brief notes on:
- (i) The objects and consequences of wool scouring.
- (ii) Crêpe yarns.
- (iii) The special yarn requirements of the hosiery trade.

(3) State and account for the chief differences between three of the following :
- (i) English and Continental spun worsted yarns.
- (ii) Wet and dry spun flax yarns.
- (iii) Continental filament rayon and spun rayon.
- (iv) Condenser and ordinary cotton yarns.

(4) With the aid of diagrams show how yarn is twisted and tensioned for winding-on in any three of the following systems of spinning : (*a*) ring, (*b*) mule, (*c*) cap, and (*d*) flyer.

Section III—Conversion of Yarns into Fabrics, and Fabrics produced by Special Methods

(1) Why are warps sized ? With the aid of a line diagram of a sizing and drying machine applicable to the type of yarn you have in mind, describe the process. What are likely to be the effects of defective sizing and drying on the yarn, on the weaving process, and in the cloth ?

(2) What do you understand by the terms " drawing-in," and " twisting " when applied to the processes preparatory to weaving ? What automatic means may be used to " draw " or " knot " threads in these processes.

(3) What is the difference between an ordinary power loom and an automatic weft supply loom ? By means of simple sketches show how the weft is replenished automatically during the weaving process.
(4) Write a descriptive account of the warp loom knitted fabric and compare it with the woven fabric and the plain weft knitted fabric.
(5) Describe the characteristics and purposes of lace fabrics.

Section IV—Conversion of Fabrics into Finished Materials

(1) In the treatment of cotton, wool or silk materials what do you consider to be the primary uses of acids, caustic alkalis, reducing and oxidising agents ?
Give the names of the chemical agents you would employ to demonstrate your answers ; indicate their actions in the processes and their effects on the materials.
(2) Through what circumstances are all-wool fabrics liable to be contaminated with vegetable matter ? Discuss the methods employed to prevent defects from this cause appearing in the finished cloth.
(3) Give one example each of a useful application of :—
(*a*) a sulphur dyestuff.
(*b*) a chrome mordant dyestuff.
(*c*) a basic dyestuff, to textile materials.
Describe briefly the procedure followed in the cases you mention.
(4) Describe the processes you would employ in the bleaching of a coloured stripe cotton poplin, assuming the coloured yarn to be dyed with fast-to-bleaching colours.

General Discussion on Lubrication and Lubricants, October 13th, 14th and 15th, 1937

In response to the invitation of the Institution of Mechanical Engineers the Council of the Textile Institute recently decided to co-operate in the General Discussion on Lubrication and Lubricants, to be held in London on October 13, 14, and 15th, 1937. Mr. Scott-Taggart was appointed to represent the Council.

The Executive Committee, after consultation with the co-operating Societies and Technical Institutions, has arranged for about 100 papers, which are divided into four groups :

I Journal and Thrust Bearings,
II Engine Lubrication,
III Industrial Applications,
IV Properties and Testing.

The importance of the subject is so obvious that it needs no emphasis. Research on lubrications in the past has been very extensive and considerable information may be found scattered in the technical literature. It is felt that the time is ripe for the preparation of a comprehensive review of the state of current knowledge. The subject is one of inherent difficulty and the fundamental characteristics of lubrication are imperfectly understood. In a general discussion there is an increased probability that the subject will be approached from every possible point of view. Correlation may thus be established between theory and practice.

In no branch of industry is lubrication of greater importance than in the production of textiles. Many different types of machines have to be run under very widely varying conditions. In the textile industries, therefore, it is possible that lubrication has to be studied and applied in a more general way than in other branches of industry.

Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application :—

No. 161—Desires position as Manager or Assistant Manager. Twenty-three years experience in furnishing fabrics. Conversant with all processes. Evening School lecturer in Textile Weaving and Designing. City and Guilds Certificates in Woollen and Worsted Weaving and Designing. A.T.I. Age 40 years.

No. 162—Young man, 27 years of age, desires position as Manager of Worsted Manufacturing concern. City and Guilds Certificate in Woollen and Worsted Weaving. Four years part-time lecturer on Weaving Mechanisms. Willing to go abroad. A.T.I.

No. 164—Desires position in any type of supervision, control or advisory work in textile machinery, weaving or merchanting. City and Guilds Certificate in Woollen and Worsted Finishing. Diploma of Bradford Technical College. Willing to go abroad. Age 32 years. A.T.I.

No. 165—Requires position as Technologist or Chemist-Dyer. Higher National Certificate in Chemistry and Dyeing. City and Guilds Certificates in Cotton, Wool and Silk Dyeing and in Woollen and Worsted Cloth Finishing. Three years experience as Chemist and Dyer. Age 24 years.

No. 166—M.Sc.Tech. with two years experience as Assistant seeks position of responsibility in the cotton, flax or jute industry, preferably overseas. Knowledge of English, French, German and Polish. Age 25 years. Single.

Institute Membership

At the June meeting of Council, the following were elected to Membership of the Institute :—

Ordinary

H. Arrowsmith, Yorkshire Dyeing & Proofing Co. Ltd., Spring Vale, Middleton, Manchester (Managing Director).

A. J. Borin, M.A. (Cantab.), B.Sc. (Lond.), 46 Stanley Road, Broughton Park, Salford 7 (Chief Chemist, Yorkshire Dyeing & Proofing Co. Ltd., Middleton).

K. C. Brown, B.Sc. (Lond.), M.Sc.Tech., 37 Fellows Road, South Farnborough, Hants. (Assistant, Royal Aircraft Establishment, for research).

G. E. Collins, M.Sc.Tech., 7 Hawthorn Avenue, Wilmslow, Manchester (Senior Research Assistant, Testing Dept., British Cotton Industry Research Asscn., Manchester).

Wm. Crossley, "Cranleigh," The Hough, Wilmslow, Cheshire (Director and Manager, Yorkshire Dyeing & Proofing Co. Ltd., Middleton).

G. Harris, "Fernlea," Whalley Road, Wilpshire, nr. Blackburn (Cotton Mill Director).

J. J. Sanderson, 4 Brunswick Street, Carlisle (Yarn Buying and Designing, R. R. Buck & Sons, Ltd., Carlisle).

H. Sommer, Prof. Dr. Ing.; Staatliches Materialprufungsamt Berlin-Dahlem, Unter den Eichen 86, Berlin-Dahlem, Germany (Head of Fibre Department).

Junior

H. D. Sampat, c/o Kiryu College of Technology, Kiryu, Guma Prefecture, Japan (Textile Student).

A. J. Whitehead, Whitehead Industrial Trust Ltd., Mitre House, 177 Regent Street, London, W.1 (Manager).

Reviews

Modern Drafting in Cotton Spinning. By J. Noguera. Printed and published by Chorley & Pickersgill, Leeds (pp. 193, price 9/6).

The publication is a revised edition of the work of the Author, in 1934 (pp. 113), under the title of the " Theory and Practice of High Drafting in Cotton Spinning " to which has been added a considerable amount of valuable information relating to the drafting of cotton, and mixtures of fibres. In the preface the author states that he gratefully acknowledges the widespread interest which has called for the publication. In this respect there is no doubt that the subject of drafting cotton, with the effects, limitations and comparative costs, has received more serious consideration during the past 20 years, than any other operation in the whole of the spinning processes, with considerable benefit to the industry.

The subject matter is well arranged in order of development, and careful indexing adds to the value of the contents as a book of reference. Drafting cannot, however, be seriously considered in relation to the ultimate yarn efficiency, involving its quality and price, without full consideration being given to the characteristics of the material, and unfortunately there is very little consideration given to these. Approximately 70 per cent. of the contents definitely relates to the development, application, uses and effects of the various Casablancas devices, and excellent though these are, such a work is incomplete without more detailed consideration of other successful arrangements. Again in his preface, the author recognises this limitation and expresses his regrets that limited time has been to his disadvantage.

Referring to double feeds to speed frames, ring frames and mules, the statements that " these improve, or rather maintain somewhat the irregularity in weight per unit length " and " in this respect the doublings are often a real though quite indirect cause of unevenness in the final yarn " are contradictory. There can be no doubt that generally double feeds are beneficial in the resulting yarns.

The consideration of evenness in yarn is excellent, though the author has dealt only with the production of yarn from cotton with the maximum dispersion of staple lengths, and on this material alone he criticises the whole of the " ordinary roller systems." Given combed types of cotton, it is possible to produce excellent yarns by roller drafting, which are reasonably free from the thin places and clots depicted.

The author has very effectively and logically shown the limitation values of " doublings " in relation to yarn values, but taking his diagram Fig. 2 in relation to the possible chances of variations, his expressions are incorrect regarding the chances of percentage variations, which should be :—

18 chances of 0 per cent. variation.
16 chances of variation between + and − 12·5 per cent., not ± 6·25 per cent. variation.
2 chances of variation between + and − 25·0 per cent., not ± 12·5 per cent variation.

This variation grouping also affects the statements given later for 6^3, 6^4, 6^5 and 6^6 for an increasing number of slivers. There is much helpful fundamental treatment, of drafting in cotton spinning, but its value could have been increased with a little more consideration of drawing roller methods.

The section on drafting by rollers could have been made of much greater assistance by some discussion of the extensive treatment that has been applied to the second control rollers, by alterations in weight, settings, nature of the surfaces, and their relation to drawing.

The development of high drafting by the Casablancas system is lucidly dealt with, though when considering different systems for high drafting, the four lines of rollers and other systems receive very scant treatment. The four line roller systems and the one band drafting devices are producing excellent qualities of commercial yarns.

The outstanding feature of the work is that relating to the Casablancas systems of to-day. Here much useful information is available regarding this form of drafting on mules and ring frames, though in the former instance, for fine spinning mules on good cotton, it is questionable whether the advantages

gained warrant the cost of the change. The whole of the many modern refinements are closely examined and the reducing collectors for the elimination of fluff and fly cotton give evidence of the care with which the drafting system has been developed.

In connection with the practical utilisation of the Casablancas system of drafting, very sound recommendations are offered to help spinners who desire to give consideration to its application, in the many different ways in which it can be introduced. As regards the economics of high drafting for spinning, the relative proportions of preparation machines necessary, according to the method of application and requirements, are given in detail. These proportions have been reduced to comparative percentages according to draft, count and machine, or machine spindles omitted, and should serve as a useful guide to those contemplating using the system. It is unfortunate that the usual error of grouping as a total, all the speed frame spindles, has been carried out on an equal cost basis for the percentage saving in preparation expenditure, which is definitely incorrect. The problem under consideration is that, based on an ordinary spinning mill, the speed frame spindles are shown as 100 per cent., then with differing drafts and a reduction in intermediate and slubbing spindles (roving spindles omitted) on high draft spinning, the reduced total spindles are taken in the total ordinary spindles basis as a percentage of the cost of preparation. This is incorrect as a roving spindle is considerably cheaper than a slubbing spindle but this is not taken into account. Therefore the percentage cost of preparation and saving in expenditure are incorrect as given. The same criticism applies to the comparison when all the three speed frame passages are retained, but with a reduction in the number of spindles in each passage. The percentage saving in expenditure can only be obtained by considering the current cost, or price paid, for each slubber, intermediate and roving spindle and they should not be grouped together to indicate that each spindle costs the same amount. This irregularity is proportionate preparation spindle percentage should also be considered in the comparison made later in a 60,000 spindle mill.

The consideration given to yarn produced by high drafting, as regards strength, quality, price of cotton, or cheaper processing which is left to the discretion of the spinner is very good, though it is not wise to make a fetish of strength alone, without considering, to some extent, the extensibility of the yarn.

Under the problem of yarn contraction, it would lead one to the conclusion that because the yarn contracts due to twist, after delivery by the rollers, that the diameter of the yarn increases with the contraction. This can hardly be the case, but that the yarn becomes more compact.

The matter relating to single process preparation and extended control is very topical and the latter of considerable importance to spinners who have to deal with the spinning of yarns from mixtures of fibres with extensive differences in staple lengths, similar to flax and cotton, wool and cotton or silk and cotton. Even here the nature of the surfaces of the fibres in contact would have a large share in the yarn efficiency.

Some useful practical information is to be gained from the section dealing with the twist in rovings, break drafts, diameters of front rollers, tensors and flick clearers.

The compound drafting system is clearly explained and worthy of further consideration by spinners of some types of cotton yarns. On the whole there is much that is good in the book, which should be useful to the person who is anxious to obtain a good knowledge of intense or high drafting.

There are a few simple errors which will, undoubtedly be read correctly by the reader, as for instance when reference is made to compound drafting—on easy threading—Fig. 62 is mentioned for reference, instead of Fig. 61.

H.B.

Patents for Inventions. By Reginald Haddan, Fellow of the Chartered Institute of Patent Agents. London, Sir Isaac Pitman & Sons, Ltd. (3/6 net.)

If it is agreed that those engaged in Industry should possess an elementary and superficial knowledge of Patent Law, then the present book can be wholeheartedly recommended. In concise but adequate form, Mr. Haddan

tells the layman all he requires to know of the fundamental laws—or regulations—relating to Patent Applications. But if there is one lesson to be learnt from this useful little work it is, that danger lies in advancing far into the complexities of the Patent Laws without a guiding hand; in other words, the assistance and advice of a Patent Agent. Mr. Haddon, it will be noted, refers to the amendments to the Patents Acts which have " tended to destroy the local coherence of the Law as whole and rendered its employment difficult." Apart from the detail of the regularised and correct methods to be employed in order to secure a Patent, the author adds many words of advice which are valuable and indicate a very close knowledge, observation and record of the possible mistakes made by applicants, many of which may be fatal. It has been laid down that no Patent can be said to be really valid unless it has passed the test of a Hearing by the House of Lords. This being the case, although the inventor can learn quite a lot from such a book as Mr. Haddan's, his safest course, if his invention is one of moment, is to entrust its Patent safety to one versed in the ramifications of a very complex law. F.N.

Lancashire and the Future: The Present Position and Prospects of the Cotton Industry. June, 1937. Joint Committee of Cotton Trade Organisations, Midland Bank Building, Spring Gardens, Manchester, 2. (Price, 1/-, post free.)

It now appears to be generally admitted that no longer can questions of industrial economics and trade prosperity be linked with political theories in a few positive dogmatic sentences. Even when the broadest views are adopted and the discussions are world-wide rather than national, it seems impossible to assess completely the actions and reactions involved. In the past, at the height of her prosperity, Lancashire not only forged the weapons for her competitors of to-day, but also taught her rivals how to use them. That increased local production of cotton goods throughout the world was inevitable was obvious, and refusal to instruct the foreigner could have resulted in no more than slight postponement of the conditions now existing.

In " Lancashire and the Future," there is a wise concentration on the present position and future outlook. The assistance given by successive Governments to other branches of industry is compared with that given to the cotton trade. Lancashire must feel somewhat hurt that reorganisation is insisted upon before help can be given. There is considerable evidence that efficiency in the cotton trade in Lancashire compares favourably with that in all other parts of the world. The tremendous decline in Lancashire's trade is due rather to increased local production and low wages in other countries than to low efficiency.

Many of the enormous difficulties in the way of reorganisation are perhaps peculiar to Lancashire and to the structure of the industry. It is strongly urged that Government aid is necessary for the preservation of Lancashire's overseas markets, and that with this help a greater measure of confidence and security would obtain. If Lancashire is assisted as she feels she should be, the future is not without hope. Her retention of 30 per cent. of world trade by volume and 98 per cent. of the home market (with no special tariff advantage) is interpreted as an encouraging sign of the vitality of Britain's principal export industry. T.

Das Färben und Bleichen der Textilfasern in Apparaten. By Paul Weyrich. Julius Springer, Berlin, 1937. pp. viii and 347, with 153 figures. Price RM 27.)

The bleaching and dyeing of yarns in cop, cheese and on beam have never become in this country so important as in Germany and in other textile countries generally.

The term " Apparatefärberei " in its present connotation has no exact equivalent in English; it may be translated approximately as pack dyeing, and consists essentially in maintaining the textile material in a stationary condition whilst the dye liquor is circulated through it.

A technical and historical examination of the preference in this country for methods of preparation based, for example, on warp dyeing, over those based upon cheese and beam dyeing should be both interesting and valuable, and

would doubtless be concerned in no small way with the influences exerted by our horizontal organisation in the textile industry, and by the continental vertical organisation, on industrial methods.

This book divides itself roughly into two halves, the first dealing with the dyeing and construction of plant for dyeing loose wool tops, wool yarn and cheeses, loose cotton, sliver, yarn in hank, cop, cheese and beam, and so on. The dyeing of artificial silk is unfortunately dismissed in two or three pages; a chapter on current developments in the dyeing of viscose rayon in cake form and the attempts made to dye it in cheese would have been very valuable.

The descriptions of different types of machines with a large number of excellent illustrations together give a very clear idea of the large range now available of machinery based upon the pack system of treatment, and it is equally clear that much of this machinery has reached a high level in engineering skill and efficiency. Not unnaturally most of the illustrations are of plant of German origin. There is an illustration on page 133 of a dyeing machine for cotton hank yarn of Italian origin, but there appears to be no example of English, Swiss, French or Belgian manufacture.

The second half of the book constitutes an excellent text-book on the dyeing of textile materials with an introduction to dyeing theories including an exposition of a conception of hydrogen ion concentration and the buffering of solutions. The author has not restricted himself to details of the methods of applying dyestuffs in pack machines, but deals in a most interesting way with the modern dyestuffs and auxiliary products, and collects in a convenient form a large amount of useful information, not easily obtainable, about the special properties of dyestuffs both in the dyeing process and in the dyed material including for example the work of Kayser, Ruperti, Löscher and others, on the after treatment of Naphthol AS combinations and their influences on light and rubbing fastness, and refers to the researches of English workers upon the tendering action of vat dyestuffs in air and in hypochlorite solutions.

The reviewer's impression of the book is that it is well informed, comprehensive and accurate and reaches the high standard characteristic of the best German handbooks in this branch of technology. F.S.

Venticinque Anni di Attività della R. Stazione Sperimentale per le Industrie della Carta e delle Fibre Tessili Vegetali. (Milan, 1936; 161 pages; Quarto).

This is a handsomely printed and illustrated record of the first twenty-five years' work of the Italian Research Station for the paper and vegetable fibre industries, compiled by its well-known director, Dr. Camillo Levi. An interesting account is given of investigations into the production of pulp and fibre in Italy and the final section describes the research institute and its equipment. There is an air of dignity and spaciousness about the administrative rooms, and the laboratories appear to be supplied with a wide range of testing machines. A novelty, from the British point of view, is a refrigeration plant utilising methyl chloride. The laboratories and workrooms are now being greatly extended—a fitting celebration of the close of 25 years of useful work. W.

Methods for the Detection of Toxic Gases in Industry. Leaflet No. 1. Hydrogen Sulphide (Department of Scientific and Industrial Research). Published by His Majesty's Stationery Office, 1937. Price 3/6 net).

In the foreword to this important publication, reference is made to Regulation 7 of the Chemical Works Regulations, 1922 (Section 79 of the Factory and Workshop Act, 1901). This insists on the testing by a responsible person of any vessel or place thought to contain a dangerous gas or fume, before it is entered by persons without approved breathing apparatus and life-belts. The production of the leaflet is the outcome of discussions between the Association of British Chemical Manufacturers and the Home Office. The Department of Scientific and Industrial Research arranged for a series of tests to be developed by the Chemical Defence Research Department.

The intensely poisonous character of sulphuretted hydrogen or hydrogen sulphide is emphasized. In concentrations above 1 in 1,000 by volume hydrogen sulphide causes immediate unconsciousness, resulting in death unless artificial respiration is immediately applied. At such concentrations it is nearly as

poisonous as hydrogen cyanide or prussic acid and may act with equal rapidity by paralysing the respiratory centre of the brain.

Of the four methods of detection considered that in which a known volume of the atmosphere is drawn through the test paper, has been adopted as being the most satisfactory from all points of view. Complete detailed instructions are given for carrying out the test, including the preparation of the lead acetate test papers. Drawings are given of the hand-pump attachment in which the test paper is clamped and the sizes of the essential parts of the pump are specified. Standard stains, with which the stain on the test paper is compared, are printed on a sheet carried in an envelope in the cover of the leaflet. From the intensity of the stain the concentration of hydrogen sulphide may be determined.

The series of leaflets of which this is the first to appear should be of great assistance to all engaged in those branches of industry to which the Chemical Works Regulations 1922 section of the Factory and Workshop Act apply. T.

Additions to Library

On the Warp Let-off Motion of the Loom. Y. Nogamy. (Nogamy Automatic Loom Works Ltd., Gohisco, Nagoya, Japan.)

Manual for the Dyeing of Cotton and other Vegetable Fibres, 1936. (I. G. Dyestuffs Ltd., 14 Bridge Street, Manchester, 3.)

JULY 1937

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXVIII JULY 1937 No. 7

PROCEEDINGS

Council Meeting, July, 1937

An excellent attendance of members gave attention to several matters of interest and importance included in the Agenda for the meeting. The recommendation that the Chairman of the Unification of Testing Methods Committee be a member of the Finance and General Purposes Committee was accepted. The London Section Committee sent forward a cordial invitation to Council to hold one of its monthly meetings in London sometime in the near future. The President and General Secretary were asked to interview the Section officers in the matter and to report to the next meeting of Council. The Textiles and Designs Committee reported that it was not yet possible to make a full report on the awards in connection with the Annual Competitions and this Committee was accordingly authorised to proceed with the matter without further confirmation. It was reported that Mr. Frank Pick, Chairman of the Government Committee on Art in Industry, had kindly consented to distribute the competitions prizes this year and the date fixed was Saturday, 9th October. Mr. H. P. Curtis, the newly-appointed Hon. Secretary of the Lancashire Section, Mr. Enos Lees having resigned for health reasons, was in attendance and was welcomed by the Chairman. A report on the Institute's Examinations was submitted and adopted and the list of successful candidates appears hereunder. A report and recommendations by the Unification of Testing Methods Committee was submitted and adopted and authority given to that committee to proceed in the setting-up of a special Committee to deal with certain prescribed aspects of Standardisation. Authority was given for a note to be issued to the Press early in September giving full particulars of the scheme.

Examination Awards: 1937.

The results of the current year's Examination in relation to the Associateship of the Textile Institute, held simultaneously at Manchester, Bradford, Nottingham Glasgow, London, and Bombay (India), have just been issued, and the following passes are recorded :—

Part I (Auxiliary Subjects)—*S. Angus (Bolton), S. Burtonwood (Bolton), F. Webster (Bolton).

Part II (General Textile Technology)—*J. Airey (Blackburn), J. Ashton (Oldham), Wm. Bradley (Yeadon), A. S. Cluley (Nuneaton), *S. J. T. Durrell (By Renfrew), *J. Frame (Dundee), *J. Gooddy (Derby), G. Helliwell (Halifax), D. Higson (Bolton), *F. Ingham (Paisley), *R. Jones (Shipley), *H. Law (Keighley), *E. Leach (Wolverhampton), J. H. Lee (Burnley), *F. Marsh (Pudsey), N. Mellray (Bolton), *W. Penn (Coventry), *R. O. Scott (London), *J. Smith (Bradford), W. Townend (Halifax), *J. R. West (Silsden), *R. Williamson (Luddendenfoot).

Names marked with asterisk are of candidates who have now completed the qualification requirements in regard to award of Associateship (A.T.I.).

TEXTILE INSTITUTE DIPLOMAS

Elections to Associateship have been completed as follows since the appearance of the previous list (June issue of this Journal) :—

ASSOCIATESHIP

JOHNSTON, Daniel (Colne).
WRATHALL, Richard Thomas (Derby).

Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application :—

No. 153—Desires position as Textile Technologist or Technical Advisor or Responsible or Managerial post to Private Firm or Public Body. 15 years' experience in Hosiery Trade. 5 years at Public Testing House, and experience in lecturing. Knowledge of Costing, Factory Management, Past Examiner. A.T.I. Fellow of Microscopical Society. Age 34 years. Prepared to go abroad.

No. 164—Desires position in any type of supervision, control or advisory work in textile machinery, weaving or merchanting. City & Guilds Cert. in Woollen and Worsted Finishing. Diploma of Bradford Technical College. Willing to go abroad. Age 32 years. A.T.I.

No. 165—Requires position as Technologist or Chemist-Dyer. Higher National Cert. in Chemistry and Dyeing. City & Guilds Certs. in Cotton, Wool and Silk Dyeing and in Woollen and Worsted Cloth Finishing. 3 years experience as Chemist and Dyer. Age 24 years.

No. 166—M.Sc. Tech. with two years' experience as Assistant seeks position of responsibility in the cotton, flax or jute industry, preferably overseas. Knowledge of English, French, German and Polish. Age 25 years. Single.

No. 167—A.T.I., 43 years of age, desires position as Representative for Textile Machineries, or Accessories; Supervision or Executive work. Full Tech. Cert. in Cotton Carding and Spinning and sub-processes. Control and Managerial position over long period with Cotton Spinning and Manufacturing concerns. Certified Textile Engineer, etc. Eastern experience. Willing to go abroad.

Institute Membership.

At the July meeting of Council, the following were elected to Membership of the Institute :—

Ordinary

J. Brooks, 38 Warwick Road, Lytham St. Annes, Lancs. (Technical Editor, "Textile Mercury & Argus" and "Hosiery Times").

R. B. Brunton, 61 Selborne Gardens, Hendon, London, N.W. 4 (Textile Viewer, Aeronautical Inspection Directorate).

D. J. Burton, 53 Dorchester Road, Western Park, Leicester (Mechanic and Part-time Demonstrator, Leicester College of Technology).

J. M. Cole, B.S., M.S., Cold Spring Bleachery, Yardley, Pennsylvania, U.S.A. (Vice-President, Textile Finishers).

A. Hartley, 28 Waverley Road, Great Horton, Bradford (Clerk in Counting House, Hield Bros., Ltd., Bradford).

R. Peel, 26 Warham Road, Croydon, Surrey (Technical Advisor on Knitting, etc., Subsidiary of Courtaulds Ltd.)

Elsie Ross, A.R.C.A., Jaonnet, Bramhall Road, Woodford, Cheshire (Textile Designer).

L. A. Smith, Lyne-Cote, Sibson's Road, Birstall, Leics. (Assistant Departmental Manager).

J. H. Whitehead, B.Sc. Tech., 6 Kings Avenue, Oslo Park, Gatley, Cheshire (Textile Technical Assistant).

Junior

B. Gee, 4 Rochdale Road, Sowerby Bridge, Yorks. (Student).

M. Grossu, B.Sc.Tech., Str. Tf. Ton. Nou 34, Bucharest, Roumania (Student).

W. Huggan, B.Sc. 14 Westwood Crescent, Leeds 6 (W. & T. Huggan Ltd. Bramley).

B. C. Mehta, Mandvi's St. Lalabhai's pole, Ranchhod Khancha, Ahmedabad, India.

K. Schlesinger, B.Sc. Tech., 49 Burton Road, Withington, Manchester.

G. Smith, 5 Palmerston Street, Woodborough Road, Nottingham (Assistant, Nottingham Yarn & Testing Bureau).

MATHER LECTURE, 1937

AGRICULTURE AS A POTENTIAL SOURCE OF RAW MATERIALS FOR INDUSTRY?

By SIR HAROLD HARTLEY, C.B.E., M.C., F.R.S.

A story is told of Jowett that when an old pupil went to him for counsel before leaving England to fill one of the great posts of the Empire, the old Master of Balliol's only response was the oracular advice " Never explain, never apologise." But I feel that I owe you certainly an explanation, if not an apology, for having chosen as my subject one on which I am the first to admit that I am not qualified to speak. When you did me the honour of inviting me to give the Mather Lecture I was rather at a loss to find a subject in which we had a common interest, until it occurred to me to speak to you about the movement in the United States illustrated by the Dearborn Conference, at which representatives of industry, agriculture and science meet each year to discuss new means of developing the use of farm products in industry. But as this development in America represents only a particular phase of the general problem, I have chosen as my subject " Agriculture as a Potential Source of Raw Materials for Industry ? " I am asking a question which it would take a team of experts to answer adequately, though probably without agreement, but perhaps it is useful on such an occasion as this to ask a question, if it is sufficiently provocative. And this question is certainly intriguing—to what extent is agriculture likely in the future to supply the raw materials for industry in addition to food and textiles, her main customers to-day ?

The answer involves a forecast of both demand and supply : whether the demands in the future are likely to be of the same nature as at present, and whether fundamental changes are likely in the ways of meeting them, either in materials or methods of manufacture. To-day our materials are mainly traditional in character, and changes in methods of manufacture have hitherto been due in great part to mechanisation.

Anyone who tries to forecast the future is foredoomed to failure. He may adopt the method of extrapolation from the present position and his knowledge of the past, or he may give rein to his imagination and dream visions of Utopia, and on the whole the dreamers have probably been more successful than the extrapolaters like Malthus and Crookes, whose prophecies of excessive population and a shortage of fertilisers were soon to be falsified by new developments.

Nevertheless, in expanding my question and exploring the considerations necessary to give an answer, I shall take the line of extrapolation, as dreamers are apt to forget the mundane but most essential element of cost. Force of circumstances has made me " net revenue minded," and thereby unfitted me perhaps for the part of a prophet.

The two avenues of approach I have mentioned are analogous to the aims of fundamental and applied research. The goal of the former is as complete an understanding of natural phenomena as is possible at each stage of knowledge, irrespective of its practical utility or its relations to human life, while the latter aims at applying this fundamental knowledge to such practical problems as seem to offer some opportunity of an economic solution. The opinion is not uncommon in modern writers that this use of scientific knowledge is hampered and opposed by the vested interests of existing industries and by the fear of capital obsolescence. The increasingly rapid

progress of many industries is a convincing answer to this criticism, and those who are impatient because industry appears to lag behind in the wake of discovery are apt to forget that, while knowledge opens up new vistas of the possibilities of change, it has also afforded us new means of judging whether the prospect of such changes being economical brings them into immediate practical consideration. For instance, thermodynamics can tell us the magnitude of the energy changes involved in chemical reactions and the conditions under which they will take place if a suitable catalyst is found, and thus we know the limits of their practical application.

In that most stimulating lecture, "The Retreat from Reason," Professor Hogben argues that there is nothing miraculous about coal and that we can manufacture the complex organic molecules we need from the disintegration products of any organic matter we choose to employ. "Private enterprise condemned us to go underground to look for them. We have covered ourselves with dirt in doing so." He quotes the ease (?) with which an aromatic compound (mesitylene) can be made from acetone, a plant product. But the reason why so many materials are made from coal tar is that it is the cheapest method of preparing them; other routes are possible, but at present they hold out little chance of competing commercially. This is not a plot of the industrialist, but his effort to make the best use of his available materials.

Dr. Bernal, in his fascinating forecast, "Science and Industry," in the "Frustration of Science," speaking of the coming replacement of iron and steel by the lighter metals, aluminium, magnesium and beryllium, says "iron and steels will no longer be used indiscriminately for structure and machinery. They will be kept for tools and working surfaces. This change is held up by the immense vested interests of the iron and steel industries." I suggest that the real cause is the fact that aluminium is far more costly to extract from its ores than iron. The cost of energy alone required for the reduction of a ton of aluminium from its oxide is several times as great as the total cost of production of a ton of iron. Hence it is surely misleading to speak of "the replacement of the heavy metal economy of high energy expenditure and localised sources of material by light metal alloys from universally distributed sources which can be made available for use without the necessity of high temperature processes."*

The aim of the scientific idealist is presumably to meet human needs with the smallest expenditure of energy, and I cannot understand this antipathy to coal, the source most likely to provide the cheapest energy units (apart from the limited amount of cheap water power that is available) until we have found a method of utilising the sun's radiant energy by photoelectric cells or of tapping the energy of the atomic nucleus.

I may seem to have wandered far from my subject, but I have done so deliberately to explain why I am going to take a short range view of immediate practical developments, rather than explore the more spectacular possibilities of a new order of knowledge and human achievement. I agree entirely with Professor Hogben and Dr. Bernal as to the significance of biochemistry and biotechnology, but their value will be judged largely by their power to save expenditure of material and energy.

Let us consider first the plant as a chemical factory, the variety and nature of its products, and as a sequel the relations of chemical industry to agriculture, both as a rival producer and as the processor of farm and forest products. Then, in order to get our problem into better perspective, let us

* L. Hogben. *The Retreat from Reason*, p. 67.

take the output of agriculture, including forestry, and see to what extent its products are already utilised in industry, followed by a brief review of the present trends in that direction. Having made this preliminary survey we can then look at the American experiment as a practical gauge of the progress that is being made.

THE PLANT AS A CHEMICAL FACTORY

As producers of raw materials we can regard plants as organisms for the manufacture of a wide range of complex chemical products starting from the simplest substances—carbon dioxide, water, oxygen and nitrogen. The dominating factors for our purpose are the life cycles of different plants, the materials produced by them at different phases of growth and their segregation in the storage organs, the latter being of special importance as it determines so often the ease of separation of the products and thus their economic value.

In the place of the elaborate equipment of a chemical factory the plant produces its own catalysts and utilises the radiant energy of the sun, both for the radiation necessary for photosynthesis and the heat requirements of chemical reactions, the rate of growth being regulated by the temperature and the supply of materials.

For over a century the efforts of organic chemists have been directed to elucidating the atomic structure of the products of organic life. They were so successful that when new weapons, X-rays and electron diffraction, were placed in their hands, with which they could actually determine the positions of the atoms in the molecules, it was found that the formulæ they had deduced were very near the truth. This knowledge enabled chemists to synthesize many natural products in the laboratory, although we still have little idea of the precise course of the reactions that take place in the living cell. But ignorant as we are of the mechanism by which nature builds up these complex substances, it is clear that they contain certain structural units which give us a clue to nature's architectural methods. Her unknown catalysts are so specific in their actions and work so cleanly compared with ours, that with their help she can build up complex molecules from single units " which are evidently marshalled under the direction of surface forces and probably of templates consisting of ready-formed polymerides."*

The plant products which are of economic importance can be classified into five main groups, carbohydrates, vegetable oils, fats and waxes, essential oils, proteins and alkaloids. The study of their composition throws light, not only on their individual types of structure, which determine their properties and industrial significance, but also on the structural units from which they have been built up, some of them being common to several groups.

Carbohydrates.

The simplest of these, the sugars, are formed by photosynthesis in the green leaf from carbon dioxide and water, and they are then built up into a series of larger units or polymers of allied composition which play such a vital part in the structure and growth of plants :—starch, their chief means of storing food ; cellulose, the key substance in the fibrous structure of all plants ; hemicellulose and the pectins which cement together the fibres of cellulose ; and lignin, the woody product of growth. We know from X-ray

* R. Robinson. *Synthesis in Biochemistry*. J. Chem. Soc. 1936, 1090. See also " The molecular architecture of some plant products," Ninth International Congress of Pure and Applied Chemistry, 1934, by the same author, to whom I am much indebted for advice.

photographs that cellulose consists of long chains of linked glucose molecules as shown in Fig. 1 and that some millions of these single chains are grouped regularly in slender fibrils. These, cemented together by pectins and other material, form those fibres which are the basis of several sections of your industry.

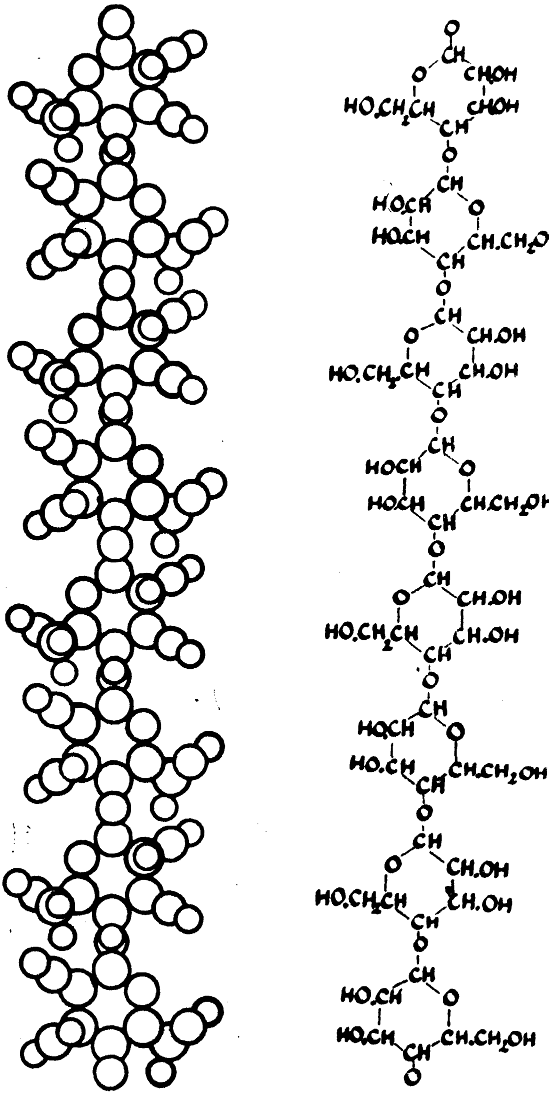


*Fig. 1. The atomic arrangement and conventional formula of part of the cellulose chain.

All these products appear to be built up from hexose units like glucose ($C_6H_{12}O_6$) containing a chain of six carbon atoms, though possibly the primary unit is a triose (glycerin $C_3H_6O_3$) containing three carbon atoms, as the units C_6–C_3 and C_6–C_3–C_6 are of frequent occurrence in plant products, while the formation of glycerin by fermentation from sugar and the conversion of lactic acid into sugar in animals shows that the transformation $2\ C_3 \rightleftharpoons C_6$ presents no difficulty to nature.

* Figures 1 and 5 are reproduced by courtesy of the author and publishers of *Fundamentals of Fibre Structure* by W. T. Astbury (Oxford University Press, 1937).

Vegetable Oils, Fats and Waxes.

These consist of long straight chains of carbon atoms with an acid group through which they are combined with glycerin to give fats and oils such as stearin or with similar long chain alcohols to give waxes. Here again there is evidence that the plant builds up long chains from units of six carbon atoms, as the most abundant natural products contain 12, 18 or 30 carbon atoms. The plant evidently has no difficulty in removing the oxygen in the sugars to give these hydrocarbon chains.

$CH_2-O-CO-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2$
$\quad -CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$
$|$
$CH-O-CO-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2$
$\quad -CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$
$|$
$CH_2-O-CO-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2$
$\quad -CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3$

Fig. 2. Formula of Stearin (Glyceryl Tristearate).

Fats and oils are segregated in the seeds of certain plants and constitute a food reserve.

Essential Oils, Resin and Rubber.

These have been formed by a different route, as instead of the unit C_6 they are all built up from the unit $C_5\,H_8$ with a branched carbon skeleton $\genfrac{}{}{0pt}{}{C}{C}{>}C{-}C{-}C$ which may be regarded as their parent substance. The formation of rubber by a process of polymerization into long chains may be represented thus :—

$$\begin{array}{cccc} C & C & C & C \\ | & | & | & | \\ C{=}C{-}C{=}C & C{=}C{-}C{=}C & C{=}C{-}C{=}C & C{=}C{-}C{=}C \end{array}$$

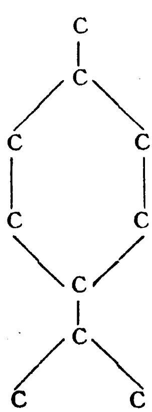
becomes

$$\begin{array}{c} \quad C \qquad\qquad\quad C \qquad\qquad\quad C \qquad\qquad\quad C \\ \quad | \qquad\qquad\quad | \qquad\qquad\quad | \qquad\qquad\quad | \\ C-C=C-C-C-C=C-C-C-C=C-C-C-C=C- \end{array}$$

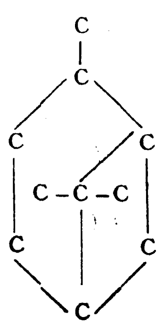
Fig. 3. Carbon Structure of Rubber.

The long chains of rubber molecules lie normally coiled up higgledy-piggledy until the rubber is stretched, when they straighten and give it those remarkable elastic properties which contribute in so many ways to our personal comfort.

But from the same C_5 unit the plant can also construct the terpenes and diterpenes which have ring structures such as :—



Limonene



Pinene

Fig. 4

The terpenes comprise the large group of hydrocarbons of the turpentine family which occur in the sap of trees, while their oxygen derivatives include substances like camphor and menthol. The resins are more complex substances of similar type containing twenty or more atoms of carbon.

Proteins.

Next come the proteins, those complex nitrogenous substances so essential to the living organism, for which we are dependent on plants, as animals are incapable of building them up from inorganic nitrogen. Plants, however, can make ammonia combine with carbon chain units, with the ultimate formation of amino-acids which have the general structure :—

$$\underset{\displaystyle R}{NH_2-\underset{|}{CH}-COOH}$$

and these molecules can combine together to form long chains such as :—

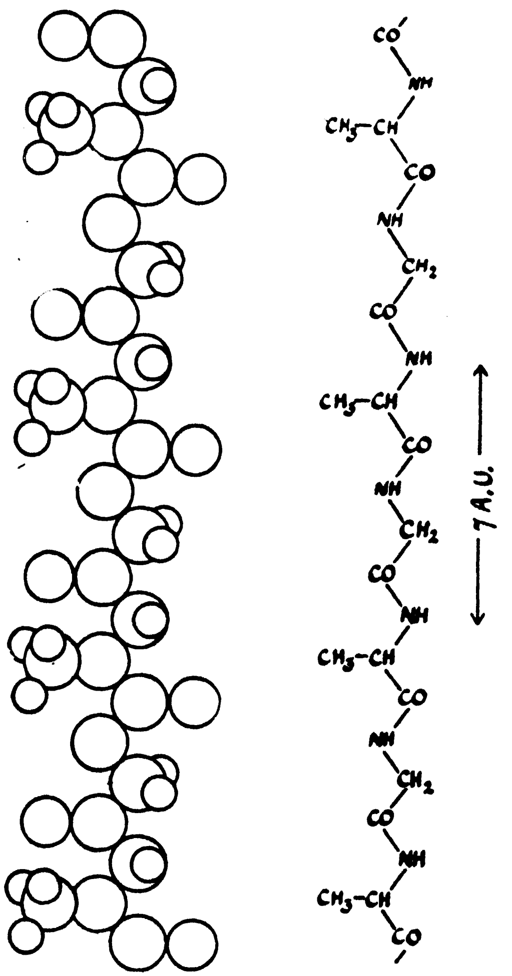


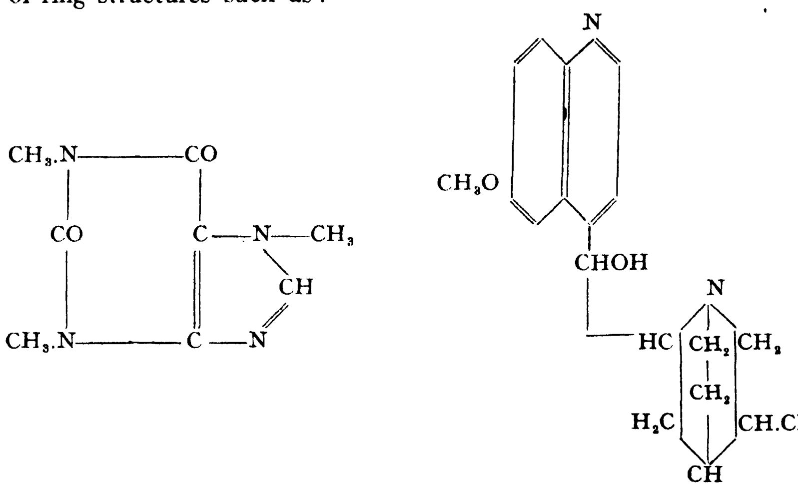
Fig. 5. The atomic arrangement and conventional formula of part of the fibroin chain of natural silk.

which X-rays have shown to be the structure of the molecular fibres of fibroin, the chief protein constituent of natural silk.

The vegetable proteins, while built up from the same structural units, are not of the fibrous but of the globular type, in which chains similar to that shown above are folded into rings.* They form a large percentage of the reserve tissues of many seeds and tubers, from which they are readily obtained.

Alkaloids.

The vegetable bases form the other group of nitrogenous plant products of economic importance, comprising that great group of substances so useful to man, the alkaloids, including atropine, cocaine, nicotine and strychnine. Closely allied to them is the family of which caffeine is the chief representative. Many of these substances also can be regarded as built up in the plant through the medium of amino-acids, but they include a great variety of ring structures such as :—



Caffeine Quinine

Fig. 6

Fundamentally the most important nitrogenous product is chlorophyll, the green colouring matter of leaves, the absorber of radiant energy, to which ultimately all things owe their activity and being—the key substance in the living world. But its existence presents us with the old problem of the hen and the egg, for while chlorophyll is essential for the synthesis of carbohydrates, carbohydrates are required to make chlorophyll.

Tannins and Anthocyanins.

The structural elements C_6 and C_3 recur again in a number of substances in which the chain of six carbon atoms has been converted into a six-membered ring with its characteristic aromatic properties. $C_6—C_3$ is the skeleton of eugenol, the essential constituent of oil of cloves, and is representative of a large class of substances with characteristic flavours. The $C_6—C_3$ group may be doubled ($C_6—C_3—C_3—C_6$) to give constituents of many resins, or with the addition of a C_6 group we obtain the skeletons of the catechins and anthocyanins. The former are the basis of many of the

* "The Cyclol Theory and the Globular Proteins," D. M. Wrinch. *Nature*, 5th June, 1937, 139, pp. 972-3.

tannins, the constituents of the bark of trees, so important in the dressing of leather, and the latter of the colouring matters which are responsible for the beauty and variety of the tints we admire in the vegetable kingdom.

This brief summary will give some idea of the variety and structures of plant products, and of the nature and complexity of their molecular architecture, which determines their properties and their industrial value. It shows too how nature is able to build them up from simple units by means of her own catalysts, with an ease and certainty that is so tantalising and intriguing to the chemist working in a non-living environment.

CHEMICAL INDUSTRY AND AGRICULTURE

The treatment of plant materials to provide soap, perfumes, dyes and spirits constituted an organic chemical industry long before anything was known of the nature of the products, and in its modern form the industry is of comparatively recent growth. It is little more than a century ago that Wöhler prepared urea from inorganic materials, and thus dispelled the idea that a ' vital force ' inseparable from living organisms was necessary for the production of organic substances. The next milestone was the preparation by Perkin in 1856 of mauveine, the first synthetic dyestuff, from aniline. Its commercial manufacture was quickly followed by that of other dyes, but the first displacement of a natural product came from the synthesis of alizarin in 1868, when the synthetic product quickly supplanted the cultivation of madder. Similarly, the synthesis of indigo by Baeyer in 1880 led to the gradual displacement of the indigo crop. But although agriculture suffered an immediate loss in this way, the rapid advance in the discovery of improved and faster colouring matters which had no counterpart in nature gave an impetus to the textile trade, the effect of which must have far outweighed the loss of the madder and indigo crops. Had the same scientific investigation been applied to their cultivation and processing as to their manufacture, perhaps the natural products might have survived.

The success of chemists in elucidating the structure of the products of organic life has enabled them to synthesise many of the most complex natural substances in the laboratory, but as a general rule nature has proved to be a cheaper producer than the factory, and is likely to remain so. Many of the so-called synthetic substances, such as camphor and ionone (the perfume of violets), are made from vegetable products in which the carbon skeleton has already been formed by the plant, and they are thus the result of chemical processing.

Of greater significance as regards the displacement of plant products has been the use of cracked oil gas and natural gas in the United States as starting points for the manufacture of organic chemicals, and also their production from water gas by catalytic processes and from calcium carbide made in the electric furnace. Here there is direct competition with the products of the fermentation industry and of wood distillation. Synthetic rubber made from cracked oil gas or acetylene is another example of this competition. It is different in composition from plantation rubber and at present is more costly, but it finds a market for certain purposes owing to its resistance to heat, oil and oxidation.

As a set-off against these possible displacements there is the important part played by chemists in the better utilisation of plant products. Few

of these occur in a form sufficiently pure for industrial use, and in many cases their utilisation depends on some kind of processing. Here chemistry has made an invaluable contribution to agriculture, and future developments of the type we are discussing depend mainly on chemical and biochemical research.

Processing may be by means of chemical reactions as in the treatment of fats and oils in their conversion to soaps and glycerin and in fat hardening, or by fermentation as in the conversion of molasses to alcohol and to glycerin, butanol, acetone and other products. Many of these play an important part as solvents in the modern methods of explosive and paint manufacture, in the purification of lubricating oils, and in the extraction of substances from raw materials. A similar example is the production of furfural from cereal wastes for use as a solvent or as a constituent of plastics.

Researches on cellulose have probably had the most far-reaching results on the utilisation of vegetable products in industry, for they have led to the development of the nitro-celluloses as explosives, paints and plastics, to the manufacture of artificial silk from cellulose or cellulose acetate, and of cellophane with its many uses. Here chemistry opened up entirely new fields for plant products.

Another development, the ultimate scope of which cannot yet be foreseen, is the discovery of synthetic plastics, with a very wide range of properties, to supplement the natural plastics which have been used for moulding since early times. These synthetic resins or plastics are made by the interaction of two substances which have the power of combining with one another, either to form long molecules which interlock, or which are linked by secondary valencies in such a way that, once formed under the influence of pressure and heat, they are infusible and insoluble. The ease with which they can be moulded into any shape, their hardness, their toughness and their electrical properties as insulators, make them most valuable in the mass production of many small articles. When used in conjunction with sheets of paper or linen they form laminated plastics which possess very striking mechanical properties. For example, they can be used for making gear wheels which are noiseless and require no lubricants, and yet show less wear than the steel gears with which they intermesh. Their electrical properties are remarkable, and it is doubtful whether the present designs of high tension switch gear would have been possible if such materials had not been available. They have been used too for making aeroplane propellers.

Plastics are still in an early stage of development and present great possibilities for the future. Two obstacles may stand in the way of their becoming a major industry; their cost is at present relatively high (moulding powder costs from £75 to £100 a ton), while the great pressures required for moulding thermoplastics are costly to apply to large articles.

But the question we have to ask is how far are agricultural products likely to enter into their composition? If we take the most important classes—celluloid consisting of nitrocellulose with 10 per cent. of camphor, casein plastics made from milk casein and formaldehyde, the bakelite family from phenol or cresol and formaldehyde, glyptols from glycerin and phthallic acid, the vinyl plastics from various vinyl esters, partly obtained from fermentation processes from molasses, and the protein plastics from formaldehyde and proteins extracted for example from soybean—several of

these substances come from agriculture, and in addition most plastics contain fillers of which wood powder is the commonest, and here is undoubtedly a field for other plant products and fibres.

Phenol is at present the most important constituent of thermoplastics, and this reveals a gap in the range of chemical substances readily obtainable from plants, namely the simple aromatic substances, benzene, phenol and cresol, which play such an important part in chemical industry. It is interesting that their main source is from the carbonisation of coal, itself a vegetable product, probably derived from lignin by the long action of bacteria, heat and pressure during geological ages, in the course of which it has lost most of its hydrogen and oxygen and formed complex carbon rings. The difference in the products of wood distillation and the carbonisation of coal emphasises the fundamental differences between them, and coal remains the cheapest source of aromatic substances which are of increasing importance for motor fuel and for the manufacture of explosives, dye-stuffs and plastics.

The study of the chemistry of plant products has thus revealed their structure and the possibility of producing them synthetically in the laboratory and in the factory. It has led in some instances to the manufacture of a substance instead of its cultivation, but on the other hand the more detailed knowledge of plant products has resulted in great developments in their extraction and utilisation. Research has also opened up completely new fields, such as the cellulose products and plastics, in which agricultural materials are finding fresh outlets.

RAW MATERIALS FOR INDUSTRY.

After this general survey of the chemical nature and utilisation of plant products, the next step towards getting a more precise view of our problem is to examine the world statistics of agricultural production, in order to see to what extent they are now being used for industrial purposes and whether possible extensions are likely to have a significant effect on agriculture.

Table I is an attempt to give the volume and value of production of thirty main agricultural products. Soft wood has been included, as within a few decades virgin forests will be exhausted and forestry will be on a cultural basis. Mr. Fraser Story, of the Forestry Commission,* in 1928 gave the following estimates of the approximate resources and annual consumption of accessible conifer forests, expressed in terms of standing timber :—

	Approximate Resources	Approximate Annual Consumption (amount cut and destroyed)
	Million Cubic Feet	Million Cubic Feet
U.S.A.	390,000	12,000
Canada	100,000	3,200
Europe	285,000	8,000
Siberia	100,000	1,000
Other Regions	110,000	1,500
TOTAL	985,000	25,700

The available supplies of soft wood could be increased if new transport facilities opened up areas at present economically inaccessible.

* Address before the Swedish Forestry Association, October, 1928.

The sources of the data are given below. The majority are only approximate estimates, but they enable us to form a rough idea of the allocation of agricultural products between food, textiles and other industrial uses.

Table I

World Production of Agricultural Produce (1927–30 basis where possible)

	Volume (million tons)	Value (£ million)
1. Milk and milk products ..	200	2,000
2. Eggs	20	1,750
3. Wheat	142	1,480
4. Rice	85	1,200
5. Pig Meat	14·5	1,020
6. Beef and veal	16·5	850
7. Maize	117	740
8. Potatoes	206	720
9. Oil seeds, etc.	45·3 (12·4)	700
10. Cotton	6·2	630
11. Oats	69	520
12. Barley	47	390
13. Sugar	28	330
14. Rye	45	320
15. Tobacco	2·4	280
16. Wool	1·8	280
17. Mutton and lamb	4	260
18. Wine	17·1	220
19. Coffee	2	190
20. Silk	0·1	180
21. Woodpulp	16	130
22. Tea	0·7	120
23. Soft Woods	250	100
24. Hides	1·5	75
25. Rubber	0·7	60
26. Jute	1·9	60
27. Hemp	1	45
28. Flax	0·6	40
29. Cocoa	1	20

Sources

1. League of Nations *Statistical Year Book* and Empire Marketing Board's *Dairy Produce Statistics* 1932 EMB/C/1.

2. Empire Marketing Board's *Dairy Produce Statistics,* 1932 EMB/C/1 and *World Agriculture* (Royal Institute of International Affairs).

3 to 8, 10 to 20, 22, 29. *World Agriculture* (Royal Institute of International Affairs).

9. *Oilseeds and Vegetable Oils,* Empire Marketing Board, September, 1932, EMB/C/4.

21. League of Nations *Statistical Year Book.*

23. *World Production and Prices* (League of Nations) and Timber Trade Development Association.

24. *International Trade in Certain Raw Materials and Foodstuffs* (League of Nations) and *Leather Trades Year Book.*

25. *Plantation Crops,* Empire Marketing Board, 1932 EMB/C/5 and International Institute of Agriculture, *Year Book of Statistics.*

26, 27, 28. *Fibres,* Empire Marketing Board, 1933, EMB/C/6.

Classification of Uses.

Food and Tobacco. 1, 2, 3, 4, 5, 6, 7, 8, 9 (part), 11, 12, 13, 14, 15, 17, 18, 19, 22, 29.

Textiles. 10, 16, 20, 21 (part), 26, 27, 28.

Other Industries. 9 (part), 21 (part), 23, 24, 25.

In arriving at separate totals the following adjustments have been made :—

Fodder crops. As Nos. 7, 11 and 12 re-appear in the food section under meat, and so make but a small net addition to farm income, they have been reduced to 1/5th for maize and barley and 1/10th for oats.

Oil seeds, etc. Tonnage has been reduced to figures in brackets for net oil (including olive and palm oil), assuming 50 per cent. to food and 50 per cent. to other uses.

Woodpulp. Textiles assumed to use 1½ per cent. of total—remainder to other uses.

Soft Woods. Reduced by 10 per cent. for pulp, shown separately.

On a value basis we then get the following percentages of utilisation :—

Food	86 per cent.
Textiles	9 ,,
Other Industries	5 ,,

It is possible to cross-check these results to some extent from the data used by the League of Nations in compiling its Indices of World Production of Primary Commodities, given in " World Production and Prices, 1935–6." In Table 4 of the Appendix to this publication the main primary commodities are shown as percentages of world production of all such commodities. The volume of each product is weighted by its 1930 price in calculating these percentages. The relevant tables for 1925–9 and 1934 are given below :—

Table II

Percentage distribution of world production of primary commodities by groups of products

	1925/9	1934
1. Food crops	19·2	19·6
2. Fodder crops	10·2	8·4
3. Meat	18·7	20·3
4. Sea fish	0·8	1·0
5. Milk	17·7	18·9
6. Wine and hops	1·2	1·5
7. Coffee, tea, cocoa	1·0	1·1
8. Tobacco	1·4	1·2
9. Oil materials and oils	2·7	2·6
10. Textile fibres	5·9	6·1
11. Rubber	0·3	0·4
12. Wood products	1·2	1·3
13. Fuels and power	10·1	9·9
14. Metals	7·7	6·1
15. Non-metallic minerals	1·9	1·6
TOTAL	100	100

It will be seen that the component series of the group totals in Table II are very similar to those in Table I, but they are not exactly comparable. China is an important producing area omitted from items 1, 2, 3 and 5 in Table II, whilst eggs are not included in this table at all. Item 12 includes

pulp, and item 10 rayon, so that there is possibly some duplication here. Hops in item 6 and whale oil in item 9 are additions to the first table; oil (item 9), as before, has been divided equally between food and other uses. Both tables exclude certain important food items (e.g. fruit, millets, pulses and many vegetables) thus tending to make the food percentage an under-estimate; on the other hand, the proportions of the main food-stuffs—admittedly small—that go to industrial uses have been ignored in our calculations.

For our present purpose, numbers 4, 13, 14 and 15 should be omitted. The remainder are agricultural in the wider sense of the term, and the percentage distribution of use can be calculated as it was from Table I. One tenth of all the fodder crops are included with food, since the bulk of their value re-appears in 3, 5 and 10 (wool). Tobacco, as before, is also included under food.

Use Distribution of Agricultural Products Calculated from Tables I and II

	TABLE I	TABLE II	
	1927/30	1925/9	1934
Food	86 per cent.	87½ per cent.	88 per cent.
Textiles	9 ,,	8½ ,,	8 ,,
Other industries ..	5 ,,	4 ,,	4 ,,

The close agreement between the estimates derived from the two tables of the proportion, on a basis of value, of the plant products used in textile and other industries indicates that they are of the right order. Zimmerman* puts the total non-food proportion, including tobacco, at 10 per cent., and as this estimate apparently excludes timber but includes foodstuffs omitted from our calculations, this again gives an independent confirmation of our results.

The consumption by industry is therefore at most only twelve to fifteen per cent. of the total production, and of this textiles account for roughly two thirds. Thus it would require a considerable expansion of industrial uses to produce marked results, although the local effect of even small variations might be considerable on marginal quantities.

These statistics suggest some other interesting points. On the basis of the League of Nations' figures (Table II) items 13, 14 and 15, which Zimmerman calls "fund resources," i.e. mineral deposits, as opposed to "flow resources," formed only 19·7 per cent. of the whole in 1925–9 and 17·6 per cent. in 1934. This decline of 10 per cent. compares with a fall of only 4 per cent. in the proportion of "flow resources" going to industrial uses,† indicating that the proportion of agricultural to non-agricultural raw materials used in industry rose over this period.

From Table II it is possible also to calculate the proportions of industrial raw materials that are derived from mineral sources and agriculture respectively. Mineral products, which go exclusively to industry, comprise some 20 per cent. of all primary commodities, while of the remaining 80 per cent. representing agricultural production, we have shown above that approximately 12 per cent. is used in industry. Hence the value of farm, field and forest products used in industry amounts at present to about one

* *World Resources and Industries*, Harper, 1933.

† Agricultural products used by textiles and other industries were 12½ per cent. of the total agricultural production in 1925-29 and 12 per cent. in 1934—see above.

half that of mineral products, i.e. to one third of the whole value of industrial raw materials.

The simplest way of attempting to forecast the possibilities of an increased industrial use of farm produce is to take the main classes of industrial materials and consider whether products derived from agriculture are likely to replace them. This will be dictated by considerations of suitability and costs. The materials must possess the required physical characteristics as regards strength, elasticity, hardness, durability, resistance to wear, stability at high temperatures, transparency, electrical and thermal properties. Then they must be suitable for manufacturing processes—casting, rolling, pressing, stamping, turning, spinning and weaving. Lastly comes the decisive factor of the cost of the finished article.

Textiles.

Starting with your own industry, all your raw materials come from the farm or forest, but the remarkable developments of rayon manufacture are gradually changing the proportions of the different products. The use in combination of different types of fibres has extended greatly the range of characteristics of textile materials. New materials are finding new uses, and the total volume of your industry increases steadily. The development of coated fabrics and of artificial leather, with their many applications, is one new and large avenue of consumption.

Metals.

This seems at first sight an unpromising field for plant products, which lack most of the properties that make metals pre-eminently suitable for many purposes ; indeed the general trend until recently was in the reverse direction—the replacement of wood by metals. However, the modern development of plastics has opened up many possibilities of replacing metal components by moulded products, with a consequent saving in weight, while reinforced plastics for special purposes can be made with remarkable physical characteristics superior to those of metals. The use of synthetic resins as adhesives and the improvements in the technique of manufacture of laminated wood now make it a successful rival to metal in many fields, for the new products possess all the advantages of wood over metals—absence of fatigue, high strength to weight ratio and resistance to corrosion, while the defects of wood due to local weakness are eliminated by the laminated structure. It is also possible to build up members of considerable size, such as aeroplane struts, under pressure without using large timber.

Rubber is another plant product that is finding an increasing use in place of metal on account of its elastic properties, freedom from abrasion and its value in reducing noise.

Building Construction Materials.

Here again the general tendency has been a reduction in the use of wood, but recently plastics have begun to find a place for smaller details, the expense of moulding objects of large size being an obstacle to their more extended use. Laminated wood is finding many applications because of its strength, lightness and low cost. A new field for plant products is insulation, both as regards noise and heat, to which so much attention is being paid in modern buildings, but many of these materials have the disadvantage of inflammability and their competition with mineral products is partly dependent on improved methods of fire proofing.

Protective Coatings and Paints.

The protection of materials from corrosion and decay and their æsthetic adornment by means of paint and enamels have undergone great changes in technique recently, and while the effect of progress has been to diminish the consumption of paint by extending its life and reducing the number of coats required, on the other hand the net demand is constantly being increased by new uses. The chief developments have been the substitution of new materials, such as nitrocellulose and synthetic resins, for the older natural resins, and the use of new solvents and plasticizers to give the necessary flexibility to the paint film. A number of these new materials are processed agricultural products, so that on the whole agriculture should benefit from the changes. The demand is more and more for closely specified materials in place of the older and cruder materials of the forest product type.

Fuel.

In many countries wood charcoal and agricultural waste are the only fuels in general use, but in industrialised countries the significant fuels are coal, lignite, oil and natural gas, except where cheap water power is available,* and it is difficult to see how wood could compete with them economically, owing to its comparatively greater bulk, its lower heat content and high cost of production.

However, in the field of liquid fuel we find quite a different situation. Alcohol is being made in large quantities by the fermentation of molasses, and in many European countries motor spirit must by law contain a proportion of ethyl alcohol. The cost of producing fermentation alcohol from molasses at 2d. per gallon is estimated at 9d. per gallon and from maize at 2/- per bushel at 1s. 3d. per gallon, while the cost of petrol at the refinery without tax is only 3d. per gallon. The addition of alcohol lowers the calorific value of the fuel but improves its anti-knock characteristics, so that with a suitable engine the fuel consumption would remain much the same. On the other hand, the use of alcohol adds considerably to the cost of production and therefore is only justified at present on strategic grounds, in order to encourage the home production of motor spirit in countries without oil resources.

As and when oil supplies begin to contract owing to the eventual exhaustion of the oilfields, alcohol may be in a better competitive position as regards the other potential sources of liquid fuel, viz., oil made from coal either by hydrogenation or by the Fischer-Tropsch process. Another possible rival fuel for use in the internal combustion engine is producer gas made from charcoal or anthracite.

Lubricants.

Lubricants are closely allied to liquid fuel, as the lubrication of the internal combustion engine and its attendant mechanisms is responsible for such a large increase in the consumption of oil. There has been a gradual shift from vegetable oils, like castor oil, to mineral oils for this purpose, and particularly for high duty bearings. But the general expansion of other uses seems to have compensated for this, as the consumption of vegetable oils shows no sign of declining, while a vegetable product, furfural, obtained by fermentation from oat husks and other cereal wastes, is used largely as a solvent in the purification of high grade lubricating oils.

* It is worth remembering in this connection that Tissot has estimated that the total available water power only amounts to 15 per cent. of the present world consumption of power, which is steadily increasing. *World Survey*, August, 1935, p. 125.

The Packing Industry.

Owing partly to the growth of trade and partly to the increased care taken to market products in good condition, there has been an enormous development of receptacles for packing articles of all kinds, and latterly of the use of cellophane and similar materials to protect goods against dirt. This has meant a great expansion in the use of agricultural products, mainly wood, textiles and cellulose in the form of boxes, bags, baling, packing and wrappers. Practically all this is of farm and forest origin—kraft paper, cardboard, strawboard, wood (plain or laminated), straw, husks and transparent films of plastics.

New Industries and Inventions.

It would be easy to extend these lists of the various fields where farm products are used in industry, but the general picture would be the same. We should find a continuous improvement in the products that are marketed, the result either of better methods of processing the traditional materials, or of their replacement by new materials. The two main factors that influence consumption are new inventions and new industries, and the development of these in turn is likely to be dependent on suitable materials facilitating cheap production. It would be difficult to evaluate the total effect on the consumption of farm products resulting from the electrical industry, the motor car industry and to a lesser extent, wireless.

THE INDUSTRIAL UTILISATION OF FARM PRODUCTS IN THE UNITED STATES.

I return now to the point from which I originally started, the organised effort in the United States " to advance the industrial use of American farm products through applied science." This is the goal of the Farm Chemurgic Council, a group of enthusiastic industrialists, agriculturists and chemists, who meet each year at Dearborn to discuss their problems, and the Proceedings of their Conferences* contain a striking record of the experiments that are being made. Their progress is of special significance, for America enjoys so many advantages for development of this kind—her position in the world both as a producer and consumer of agricultural and industrial products, her diversity of climate and soil and natural resources, the inventive pioneering instincts of her population and their belief in the value of scientific research, and lastly her vast homogeneous market of home consumers eager for novelty, which facilitates mechanised production on a huge scale.

Although America has only 6·2 per cent. of the world's population and 5·7 per cent. of the land area, in 1934 she had 56 per cent. of the world's mileage of telephones and telegraphs, 32 per cent. of the railroads, 71 per cent. of the motor vehicles, she produced 30 per cent. of the coal, 60 per cent. of the petroleum, 26 per cent. of the pig iron, 33 per cent. of the steel, 11 per cent. of the wheat, 56 per cent of the maize, 42 per cent. of the cotton, and consumed 50 per cent of the world's rubber supply.

As evidence of her confidence in scientific research it is estimated that she has 1,600 industrial research laboratories, employing 35,000 specialists, at an annual cost of approximately 40 millions sterling.

Her development entered on a new phase, the significance of which is now being realised, when the frontier reached the Pacific coast, and the happy-

*Proceedings of the Dearborn Conferences of 1935 and 1936 published by the Farm Chemurgic Council, Dearborn, Michigan.

go-lucky days of territorial expansion were over. She is now facing "the problems of matured national life,"* and the process of adjustment to a more stabilised form of society has thrown up many of the problems which the New Deal aims at solving.

One of President Roosevelt's first acts after his election was to set up a Commission to take stock of the natural resources of his country, and the Report of the National Resources Board published in 1934 is a very remarkable document, which has not had the attention in this country that it deserves. It contains exhaustive studies by groups of skilled inquirers of the land resources, water resources and mineral resources of the United States, and it presents very clearly the need for a comprehensive long range national plan for their conservation and use, in order to avoid the waste arising from selfish exploitation.

Among the long-term problems which America has to face, agriculture presents one of the most serious, quite apart from the relative price levels of agricultural and industrial commodities, owing to a variety of causes :—

1. Soil erosion.
2. Loss of fertility of land used continuously for similar crops.
3. The large extension of arable land during the war (50 million acres), much of which is unsuitable for this type of cultivation.
4. The increase of imports of farm products and decrease of exports in recent years.
5. The substitution of the tractor for the horse with its reaction on the consumption of food-stuffs and on the economics of farming.

The effort to find new outlets for farm products comes therefore at an opportune moment, and America is admirably equipped and organised for the research and development work which it entails in her Department of Agriculture with its numerous Scientific Bureaux, her chain of State Agricultural Experimental Stations, and her State Colleges. In a recent article Secretary Wallace described "101 projects for new, increased, and improved uses of agricultural products" which were being investigated by his Department. But the problem is not solely to widen the use of existing farm products, as an important aspect of it is the diversification of agriculture, by finding new crops which can be grown to advantage on some parts of the wide range of agricultural horizons which America possesses, in order to replace products at present imported from abroad, such as soybean, tung oil and starch. Similarly the cultivation of trees to help to preserve the soil against erosion or on land unsuited for other uses will help ultimately to reduce imports of forest products.

At first sight the trend towards a greater variety of crops in order to make better use of the diversity of soil and climate which America enjoys may not seem to contribute to the general world problem of the wider utilisation of farm products. But the success of these developments depends on the cooperation of industry in providing factories at suitable points for processing the raw materials and in the research necessary to find new and cheaper methods for their utilisation. The farmer is at a disadvantage compared with the industrialist in his inability to control within desired limits either the uniformity of his product or the volume of production, but the modern science of genetics has made it possible to breed improved species suited to a given

*President Roosevelt, address to the World Power Conference, Washington, September, 1936.

environment, resistant to disease, with larger and better yields. The close association of the grower and the manufacturer, with the help of the State experimental stations, should therefore provide the most favourable conditions for the development of more valuable crops.

There is another aspect of these factories for processing farm products which is assuming importance in the United States—the utilisation of farm waste. Take first the case of cull fruit or cull crops, products which because they are off-size, off-colour, or out of shape are unfit for the shipping crate. The profitable disposal of vast masses of these rejected materials presents a baffling problem, but it has been solved for the citrus fruits in California with the help of the Bureau of Agriculture. Factories have been established by the citrus fruit co-operative organisations for the production of citric acid, citrus oils, and pectin from the waste fruit, which have not only yielded a considerable money return to the growers, but also have helped to stabilise the market by providing an outlet for the surplus in years of high production.

Then there is the problem of farming by-products. For every pound of grain there is a by-product of from one to 2½ pounds of straw, stalks, and husks which required time, labour and soil fertility to produce. It is estimated that the grain belt produces each year nearly 250 million tons of these cereal by-products, and the South produces 18 million tons of cotton stalks. Only a very small proportion of this huge quantity of cellulose material has so far found an industrial use in the form of paper, straw-board, insulating material or packing, and at the present price of timber it cannot compete economically with it as a source of pulp, but its better utilisation is one of the problems under active investigation. In any case the proximity of a factory to the farm is likely to be necessary for its processing to be profitable.

It is difficult to summarise the many projects for the increased industrial utilisation of farm products, some of which are already established in production, others are in the development stage, whilst some are still being studied in the laboratory, but a few examples will illustrate the potentialities of this development.

The most important of the new crops are probably soybean, tung oil and Southern pine.

The soybean, the most important legume grown in Northern Asia, has within the last decade become a major crop in the United States, as conditions are suitable to it over a wide area and few plants can be put to so many uses. The soybean differs in chemical composition from most other crops by reason of its low carbohydrate and high protein and fat content, and it therefore possesses great potential value for industrial uses. In 1935 it was grown on over 6 million acres, and so much importance is attached to its development that the Agricultural Experiment Stations of the twelve Northern Central States have established a Soybean Industrial Products Laboratory at Urbana, Illinois, to study its cultivation and its industrial utilisation.

One ton of soybean yields approximately 250 lbs. of oil and 1,600 pounds of meal. The oil is a semi-drying oil which is mainly utilised, at present, in edible products, but is also used in the manufacture of paints, enamels, varnishes, linoleum, soap, glycerin and printing inks. The meal is used mainly for food stuffs, but owing to its high protein content a considerable tonnage goes to the manufacture of protein glues, paper sizes, washable wallpapers and protein plastics. Mr. Henry Ford was one of the pioneers

of the soybean crop as he saw in it a great opportunity to realise his ideal of developing an industrial market for farm crops. " Business is only exchange of goods. If we want the farmer to be OUR customer, we must find a way to be HIS customer." He has built a large plant at the Rouge Works for producing plastics made from soybean meal and formaldehyde and moulding them into various components for the Ford Car, the enamel of which also contains soybean oil.

The volume of farm products contained in the production of the annual output of a million Ford Cars is a striking illustration of the increased consumption that may come from a new industry. It is estimated that a million cars require :—

89,000,000 pounds of cotton, the crop from 558,000 acres, for making upholstery, brake-linings, timing gears and safety glass ;

500,000 bushels of maize, the harvest of 11,280 acres, for rubber substitute, butyl alcohol and solvents ;

2,400,000 pounds of linseed oil, the yield of 17,500 acres of flax, for making paints, core oil, soft soap and glycerin ;

2,500,000 gallons of molasses, from 12,500 acres of sugar cane, for making anti-freeze, shock absorber fluids and solvents ;

3,200,000 pounds of wool, from 800,000 head of sheep, which go to make upholstery, gaskets, anti-rust, floor-coverings and lubricants;

1,500,000 square feet of leather, from 30,000 head of cattle, for making upholstery and hide-glues ;

20,000 hogs to supply 1,000,000 pounds of lard for lubricants, oleic acid, and bristles for brushes ;

350,000 pounds of mohair, from 87,500 goats, for making pile fabric for upholstery ; and

2,000,000 pounds of soybean oil, from the crop of 10,000 acres, for making the enamel.

Another Asiatic crop which is being introduced into the Southern States is tung oil, the demand for which is constantly increasing owing to its exceptional drying qualities and water resistance in paints and varnishes. The tung oil tree has a much more limited use than the soybean and the acreage under cultivation is at present much smaller, but the oil is an essential constituent of many quick drying coating compositions, and the use of soybean oil itself for this purpose is largely dependent on the admixture of tung oil to produce a satisfactory working medium. Here again it has been found advantageous to have a factory for processing the product near at hand.

Another development in the Southern States which shews promise on a much wider scale is the work of Dr. Herty on the production of wood pulp from the Southern pine. Hitherto pulp has been made almost entirely from spruce and other timber grown in northern latitudes, and Dr. Herty's process may mark the beginning of a new industry in the South, as it opens up the possibility of using a hitherto neglected material to produce pulp, which is said to be suitable both for newsprint and as a raw material for rayon and cellophane. The cycle of growth of the Southern pine is about twelve years, and therefore much shorter than that of the spruce farther north. It re-seeds itself and grows very rapidly in the Gulf Coast States where there is a twelve month growing season and always adequate rainfall. There are over 200 million acres of this Southern pine land so there should be immense potentialities for the new industry. It only remains to be seen whether

successive generations of the same tree will grow satisfactorily on the same soil.

Turning now to the problem of finding new outlets for established crops, cotton occupies first place among the crops of America as a direct source of farm income and it furnishes more employment than any other, consequently the problem of finding fresh domestic uses for it to compensate for the decrease in exports is very pressing. About three-fifths of the cotton consumed in the United States is used for clothing and household articles and the remainder for industrial purposes. Research has been directed mainly to this latter field since it offers the greatest possibilities for extending the use of cotton.

An improved product is the best means of meeting competition, and fundamental work on fibre analysis has disclosed the influence of fibre fineness on the strength of cotton yarns, and extensive breeding and selection experiments are now in progress to improve this characteristic in American cottons, thereby strengthening the position of American growers in the markets both at home and abroad.

An important industrial use of cotton is for bags and bagging, and for this strength and durability are decisive factors. Fresh outlets are being found here, one of the most successful being the development of duplex open and close-mesh fabric bags for packing fruits or vegetables, millions of which have been sold, and also an open-mesh material for similar purposes.

Interesting experiments have been in progress for several years on the use of cotton fabric for reinforcing tarred roads. After the road bed has been levelled and primed with tar the cotton fabric is laid down and then covered with alternate dressings of asphalt, road metal and chips, which are consolidated with a heavy roller. It is reported that the surface of roads treated in this way has remained in good condition, while adjacent sections similarly treated, but without fabric, have cracked and shown signs of progressive failure. If the savings in maintenance justify the expenditure on fabric this may open up a substantial outlet for cotton.

Low grade cotton, short staple cotton and cotton linters are being used in increasing quantities for the manufacture of various cellulose derivatives, and it is estimated that in 1935 the production of pyroxylin plastics, film and lacquer, and of cellulose acetate plastics and film would have consumed the linters from nine million acres of cotton.

Maize is the most important crop in the United States in respect of acreage and value, and it occupies a pre-eminent place in the corn-belt of the Middle West, but like cotton, consumption has decreased recently and strenuous efforts are being made to find new uses for it in the Corn Research Institution at Iowa, and other laboratories. About seven per cent. of the maize crop is processed for industrial purposes in the corn refining plants of the Middle West. The main products are starch, dextrin, corn syrup, corn sugar (dextrose), corn oil and cake, while by fermentation processes the sugar can be converted into a variety of solvents such as butyl alcohol and acetone.

Most of these maize products have an increasingly wide range of uses; starch finds an application in many industries, dextrin wherever an adhesive or a binder is required, and the rayon industry alone in 1935 consumed forty million pounds of glucose. Starch may, of course, be made from many other sources, such as potatoes, wheat, tapioca and sago, and there is keen

competition between the research laboratories to find the most economical method of production.

Finally there is the solvent industry, the raw materials for which may be any sugar or starch derived from maize or other grain, sugar beet, and molasses. The highest grades of crops are unnecessary for fermentation and this industry utilises and gives the farmer a return for surpluses and those parts of his crops which would be otherwise unsaleable. These the solvent plant converts into products of significant value to industry.

It is impossible in this brief summary to do justice to the enthusiasm, the energy and the skill with which these investigations are being pursued all over America. In judging the results it must be remembered that this new line of attack is in most cases comparatively recent, and in time this great volume of research cannot fail to be effective in bringing agriculture and industry closer together through the agency of chemistry and chemical engineering. There is, too, the fact that in the United States the organic chemical industry is based on abundant supplies of natural gas and cracked oil gas as well as on plant products, and the competition between them, so long as the present abundance of oil continues, must be severe in certain fields.

I began by asking a question and I hope I have established its magnitude and its far-reaching significance, whatever may be the deficiencies, omissions and inaccuracies of my attempt to provide an answer. I have tried to examine the possibilities on an economic basis, and except in regard to liquid fuel I have not considered the recent experiments in national self-sufficiency, in which science is being used to produce substitutes for imported materials for strategic reasons without regard to cost.

I have been careful to avoid trespassing on the field of social economics, leaving to others, whose province it is, the task of working out the probable repercussions in this respect of any substantial change in the dominant demand for agricultural produce.

The results of our statistical examination, imperfect as this must necessarily be, show that while the value of agricultural products used in industry amounts to only twelve per cent. of the total world production, agriculture in its wider sense including forestry now provides approximately one third in value of the raw materials of industry—a striking illustration of the relative importance of these two types of occupation.

Then come two further questions. Is the proportion of carbon compounds used in industry, as compared with the mineral products, likely to increase ? To what extent is the factory likely to supplant nature in their production ? While the existing data hardly justify a definite answer, we have seen many ways in which the use of carbon compounds is being extended, and perhaps we are approaching a cellulose and plastics age. In spite of the triumphs of the chemist it seems clear that the factory cannot, as a rule, compete with nature in the cheap production of complex organic molecules : for supplies of cellulose, the key substance of fibrous structures, we must always rely on the plant. In fact the future lies not in the competition of nature with the chemist, but in their closer association in the production and processing of the materials requisite to human needs.

From the long term aspect of the conservation of resources such a development of the use of agricultural products is most fortunate. Our

deposits of minerals, coal and oil represent capital assets on which we are gradually drawing, with no hope of replacement, while plant growth dependent on carbon dioxide, water and the sun's radiation represents revenue without any debit to capital apart from mineral fertilisers. Under these conditions the advantage of substituting a revenue for a capital expenditure is obvious. It is true that with the present methods of scrap recovery and the improved protection of metals from corrosion our mineral resources will have a much longer life, but coal and oil once burned have dissipated their free energy.

Finally there is the social aspect of the problem. Hitherto agriculture and industry have represented divergent interests, the town and the village, the factory and the farm, the huge closely knit corporations wanting cheap food and raw materials, contrasted with the scattered, unorganised agricultural producers at the mercy of nature for their output. The modern development of factories in close touch with farmers in the processing of their goods, should bring industry and agriculture closer together and help to establish a community of interest between them. What their joint efforts can accomplish will depend on the progress of knowledge in biochemistry and chemistry on the one hand, and in plant breeding and cultivation on the other. With the modern technique of genetics and the closer association of the farmer and the manufacturer there is a fascinating prospect of new strains of plants that will yield the ideal products for industry almost to a standard specification. Then indeed we should have realized Bacon's ideal of commanding nature in action.

ANNUAL CONFERENCE OF THE INSTITUTE

SOUTHPORT, 9th–11th JUNE, 1937

The subject chosen for discussion at the Annual Conference, held at Southport on June 9th, 10th and 11th, 1937, was "The Serviceability of Fabrics for Clothing." It was planned to debate the subject on Thursday 10th, from the point of view of appearance and handle, and on Friday 11th, as regards resistance to wear. The dissertation inaugurating the first day's proceedings was contributed by Mr. C. M. Whittaker, and that for the second day by Dr. F. T. Peirce. These were printed prior to the Conference, and distributed to those attending and taking part in the discussions. They gave rise to papers from other workers which were also set up in type.

"The Serviceability of Fabrics" is a highly controversial subject which can be approached in an almost infinite number of ways. It is not, therefore, surprising, that it is impossible to divide into distinct categories the papers inspired by those contributed by Mr. Whittaker and Dr. Peirce. Consequently, all the written papers are printed first and are followed by reports of the discussions.

THE SERVICEABILITY OF FABRICS

By C. M. WHITTAKER, B.Sc.

I wish to make it clear at the outset that the opinions which I express in this paper are individual to myself as a private member of the Textile Institute. In no circumstances must they be considered to represent in any shape or form the opinions of the Company of whose staff I am a member.

When I accepted the invitation to make a contribution to this symposium I had refused previously because I said I knew nothing about fabric structure except that very elementary knowledge which one is forced to pick up by spending 37 years in the dyeing section of the textile industry. It was, however, pointed out to me that there were the aspects of colour and fastness as well as structure to be considered so that I should not be expected to talk in an expert way about structure. I am therefore accepting that wearability of textiles is an omnibus word which includes several factors amongst which may be included :—

Structure.
Resistance to light.
Resistance to washing.
Resistance to friction, perspiration, etc.
Resistance to sea water.

All I propose to say about "Cloth structure" is that it might be paraphrased as "Cloth restriction" because the main efforts appear to be directed to see how much may be left out to meet a price, and the devil take its wearability. The Sales of Goods Act (1893) states in Section 14 that a textile fabric must be of merchantable quality and reasonably fit for the purpose for which it is sold. I wonder how a claim under this section against the selling of a casement curtain containing dyestuffs of secondary fastness to light would be viewed by a judge. Actually such a claim would not be

allowed to proceed because the slogan of "the customer is always right" would be operated and the offending fabric replaced or financial compensation paid. It is, however, an interesting speculation. Would the judge interpret "reasonably fit" as demanding dyestuffs of the highest available fastness to light? Assume some expert has explained to the judge that certain vat dyestuffs gave the highest possible fastness to light attainable but were much dearer to dye than direct cotton dyestuffs of lesser fastness to light. Would the judge take the price factor into consideration: would he take the location of exposure into account, *i.e.*, a window facing North as compared with one facing South, or would he just have in his mind maximum possible fastness only? Again, would the judge consider that a fabric bought in the bargain basement should be expected to be as reasonably fit for the purpose for which it was sold as a fabric bought in another department of the store?

It is well known to all whose business is in any way connected with textiles that the shrinkage of the export trade and the consequent entry of newcomers into the home market, coupled with the financial stringency of the slump, has lead to the fiercest price competition. The textile market has been a price not a quality market all too long because the new entrants to the home market have cut prices to obtain a footing which coupled with the reduction of the amount of money to be spent has had the result that the wearability of many lines of fabrics has been a secondary consideration to the price of same.

A recent report of conditions obtaining in a certain British textile market contained the following: "The fierce competition and gradual lowering of qualities in this section of the trade in the past year or two has provided a very deplorable chapter in its history." Strong words but true of more than one textile market. All my audience must be conscious of the gradual deterioration in the quality, and therefore wearability, of many textiles in recent times.

It is, of course, debatable whether the hard wearing properties of the fabrics of a generation ago are desired by the present generation. The news cinema tells us each week that "time marches on." Taste and customs alter and the modern man would laugh at the idea of a suit only to be worn on Sundays which was the custom in my childhood. The idea of wearing for a life time a suit of broadcloth like our ancestors did has been substituted by two or three suits at 37/6—55/- and a varied assortment of flannel bags and woollen pullovers. It is as well for some modern manufacturers that the old ideas do change because it is recorded of one Roger Chown who got up a light flimsy cloth to look like English broadcloth that Chown lost one ear and was nailed by the other to his doorpost for a whole day. If the present day manufacturers of substitute cloths were nailed to a pillar for a whole market day there would not be sufficient pillars in the Manchester Royal Exchange to go round.

The textile trade must, of course, study the amount of money available for clothing. According to G. Harrison and F. C. Mitchell in their book "The Home Market" published in 1935, half the population earn money to keep themselves and the other half. The incomes run as follows: 67·6 per cent. of the working population had incomes below £150 per annum; 17·5 per cent, £150–£200; 11·5 per cent., £250–£500; 2·3 per cent, £500–£1,000; 0·7 per cent, £1,000–£2,000; 0·9 per cent., above £2,000. I always find it

difficult to believe that less than 90,000 people return an income above £2,000 per annum. I should have thought there must be that number in London alone. At the other end of the scale 15,900,000 people have incomes below £150.

I think it may be said that Woolworths and then Marks & Spencer have realised the significance of the above figures, and have reaped a rich harvest by so doing. Let us consider for one moment the policy of the chain price store of which the above two are leading examples. Judging by the regularity and high rate of their annual dividends, coupled with the many declarations of bonus shares representing undistributed profits ploughed back into the business, I think it is reasonable to suppose that the last factor which is altered to meet a rise in price of the raw materials is the profit ratio between the purchase price paid by the chain store and the selling price. Again the last thing a chain store likes to do is to raise the price of a popular line. The Chairman of Woolworths did, however, indicate at the last annual meeting that the markets may go against them so much that they may very reluctantly have to consider a new and higher price range.

Another modern retail development which has to be considered with that of the chain stores is the rapidly spreading outbreak first in London and now spreading to the provincial cities of the small shops selling every frock at one guinea. Now there is in Oxford Street, London, one shop with evening frocks at half-a-guinea. I deplore this movement. Coupled with the above two movements is the manufacture of branded articles of which the retail price is fixed by the manufacturer. I saw it stated the other day that the price of wool had doubled in eighteen months. Let us consider that fact, coupled with the modern retail policies which I have just mentioned, and its bearing on the wearability of woollen fabrics supplied at fixed prices under the above retail selling policies. I postulate that the profit ratio of the distributor is like the laws of the Medes and Persians in that it altereth not. What are the other means of meeting the increase in price of the basic raw materials, say wool? The alternatives are:—

1. Grinding the face of the manufacturer, dyer and finisher. The list of bankruptcies and annual losses shown is a measure of what an easy game this has been. Fortunately there are signs that this state of affairs is now becoming more difficult and that some sections of the trade are having the audacity to ask to be paid at least the cost price of their work, whilst others are bold enough to insist on a profit margin.
2. The quality is lowered by using a cheaper grade or mixing it with a cheaper raw material.

My point is that whichever route is followed it means a lower quality and, therefore, a reduced wearability, and it looks as if the spiral of the false boom now starting will set the firms with fixed selling prices some hard problems in this direction. Just consider the cheap taffetas now prevalent. A weaving manager of my acquaintance told me it was like weaving wind owing to the continued reduction of warp rate and pickage.

Now I do not wish to be misunderstood about modern retail policies. There is no doubt that the large quantities of one quality, style and size which may be ordered under this policy do also make it possible to supply articles of a certain standard of wearability which had hitherto not been achieved at that price. Such a policy does, however, in a rising market inevitably mean that quality and wearability have to suffer if the fixed price and fixed distributing profit have to be maintained.

Yet it is an ill wind which blows nobody any good because I read in the columns of so responsible a paper as *The Economist* " What you call a slump is a harvest time for both Woolworths and myself " : so writes a correspondent who describes himself as a " small trader," recalling, if any had forgotten it, that low prices do not in themselves mean bad times (otherwise the logical French could not term cheapness " bon marché ") nor high prices good times (otherwise even the English would not have derived the grim word " dearth " from dear).

I have told more than one group of textile buyers that the ultimate responsibility of the sale of textiles of inferior wearability is theirs. No manufacturer continues making textiles of poor wearability when he cannot find buyers for his output. I cannot see how buyers can escape from the logic of this argument, though many have been very indignant when I have told them so. Responsibility assumes knowledge of the particular branch in which responsibility has been accepted. This tempts me to ask what are the qualifications assumed to be necessary to qualify one as a buyer of any branch of textile merchandise. I am afraid technical knowledge of the merchandise is not rated very high. I believe it is true to say that the buyers of three London stores only have a technical chemist at their service for consultation on technical points such as colour fastness, strength of material, etc. When I strongly advised a managing director of a very large drapery concern that the addition of an experienced textile chemist to his staff would save him a lot of money and improve the wearability of their merchandise he would not agree. I told him immediately his suppliers knew he had a competent chemist on his staff the quality of merchandise offered to him would immediately improve.

May, however, it be concluded that the initiation of the straightforward shopkeeping movement with its desire to set up standards for the retailing of textile merchandise is a recognition—if somewhat tardy—that rubbishy textiles of poor wearability have become too prevalent and that it is desirable to endeavour to raise the standard. It is often said history repeats itself or comes in cycles. The economists have discussed and are still discussing the cycle of booms and depressions. In 1351 the Skinners of London were instrumental in obtaining a Proclamation which set out that " The common women who dwell in London and resort to the same have assumed the fashion of being attired in the manner of good and noble dames and damsels." To stop such misuse of furs they were commanded not to wear them under penalty of seizure of the furs. In 1937 common women as well as good and noble dames and damsels are encouraged to wear rayon, and for their protection not penalisation but a " quality control " scheme is started to ensure that goods of sound wearability are available. Time thus marches on without necessarily repeating itself.

Many buyers defend themselves by saying that they only deal with reputable firms—would that it were so. I recall that some years ago the Drapers Chamber of Trade asked the Textile Institute to send some technical men to discuss faults in merchandise. I was one that went. We asked to be shown some of the faults of which they complained. My colleagues and myself were amazed at the elementary faults shown us—such as dropped ends, broken picks, etc. Faults for which, no doubt, allowances had been paid by the manufacturers. The most elementary technical knowlege on the part of the retail buyer would have afforded him the necessary protection.

One practice of the retail trade which has a pernicious influence on the quality and wearability of textiles is the wide gaps they maintain between rigid selling price levels. How often have not both the textile manufacturer and processer, who have suggested an improved construction or a faster colour at a small increased cost of ½d. or 1d. per yard or even much less, been told that the extra price could not be paid because it would lift the retail price say from 1/11¾ to 2/5½, an increase of the selling price out of all proportion to the small increase in price which would have improved the wearability of the textile.

Twopence a yard on this casement fabric would enable vat dyes to be given instead of direct cotton dyes in the warp to its great advantage in wearability. This would mean 7/6 in a 40-yard job because it costs as much to make up a fugitive casement as a fast one yet the soft furnishing buyers of the retail stores are buying increasing quantities of direct cotton dyed casements.

At the risk of being told that I am talking about something of which I am ignorant it does seem to me that textile merchandise has to carry an increasing amount of overheads. Is it really necessary to have all the mumbo jumbo to be found in the modern store ? Will my shirt wear any better if I pass en route to the department an expensive seismograph or perchance to be able to get a fleeting glance of a reigning film star smothered in a popular brand of talcum powder ; such " attractions " must make their contributions to the overheads.

Speaking as a dyer there is no doubt that at various stages between the dyer and the ultimate consumer there are standards laid down which are not demanded by the ultimate consumer and which have not the least influence on the wearability and usefulness of the textile. I have here four labels for which the coloured viscose was dyed in my dyehouse with vat dyestuffs. One of these labels is the standard and the other three represent the dyeing to the standard which dyeing was rejected for being off shade. I offer no prize to the person who picks out the standard. Is it conceivable that the microscopical difference in shade between the labels would influence in the eyes of the ultimate consumer the sales appeal or the wearability of the garment to which it was sewn. I refused to accept the rejection on the grounds that it was unnecessary and unreasonable.

Here is another case of two brown elastic braids. In the first place consider the use of this elastic braid. A large portion of it will be used inside a gathered seam and will never be seen by the ultimate consumer, yet the braid manufacturers wished to reject the yarn for being off shade.

It is part of my occupation to dye viscose rayon skeins for the lingerie and smallware trade in which the variety of the shades and the hairline distinction between the tones demanded is ridiculous. I have dyed for one firm in 8 months 104 pinks. This variety of shades is not the demand of the ultimate consumer, and has no bearing on the wearability or attractiveness of the final garment. The justification put forward for this demand is that all the accessories must match the main body of the garment. What is the final result in actual fact ? Look at any display of corsets in any shop window. Once I spent two hours in Manchester on this quest. The result was that I issued the following challenge to a complainant : I would pay a guinea for every corset displayed in the centre of Manchester in which the accessories matched the brocade if I was paid one guinea for every corset in which the accessories did not match. My examination showed that the

higher the price of the corset the greater the diversion in shade between the brocade and the accessories. My enquiries have also convinced me that it is a point to which the average ultimate purchaser pays no attention. The point which I hope I have made is that there is an unnecessary insistence between the dyer and the ultimate consumer on fine points which have no bearing whatsoever on the attractiveness or wearability of the garment. On the other hand this insistence in useless points does add unnecessarily to the cost of the article because a reasonable standardisation of shades would lead to lower costs due to the bigger bulk orders which would ensue and the simplification of stocks. Moreover, this lowering of price would be obtained by the application of common sense and not by the all too often lowering of quality.

It always seems to me that manufacturers as a class have a great lack of knowledge of dyestuffs and their fastness, because ignorance is the only explanation of some of the weird combinations of fast and loose dyes found in one and the same fabric.

A worsted manufacturer will pay great attention to every stage of his process to taking the grey piece off the loom and has no knowledge whatsoever of the dyeing process which controls the saleability and in some respects the wearability of his pieces. He cheerfully proceeds to pay a price for dyeing which, if he had any knowledge of dyeing, he would know was not the price for a good job but must result in inferior work.

As I was once passing a shop in Hanover Street, London, I saw a cotton tie in a shop window with a " fadeless " label on it. I was curious as to why ties should be labelled " fadeless " because I did not think that the average man would demand that his tie should be fadeless. I therefore bought one for examination. Analysis showed that one thread was dyed with sulphur colours and one with vat colours. This construction shows ignorance on the part of some manufacturer because I find it hard to believe it was done deliberately. Seeing that one thread was dyed with sulphur colours it was a misdescription to label it " fadeless " even using " fadeless " in its present commercial misuse. Again it is obviously ridiculous to use for making tiecloth one vat dyed thread and one sulphur brown thread ; either one thread is too fast or one thread is too fugitive. To justify the fadeless label in its present commercial application both threads should have been vat dyed ; personally I think it is unnecessary to put vat dyes into tiecloth. Another case of ignorance or lunacy occurred in a four-fold fancy coloured yarn used in a casement cloth. The four threads were :—

Emerald Green .	Basic.
Dark Green . .	Caledon Jade Green.
Tango	Direct Cotton.
Brown	Direct Cotton.

and ironically the heaviest dyed shade of the four, namely the dark green was vat dyed. The casement cloth was the subject of fading complaints naturally, and I was asked to investigate the cause of the fading. I can only conceive ignorance as the reason why a yarn doubler ever made the above absurd combination.

Great claims are made as to the efficiency of the British textile trade but it has some peculiar ways of showing it.

Let us consider for a moment the dungaree trade. As regards wearability I have always considered that the heavy sizing of dungarees does not reflect favourably on the intelligence of the textile trade. The warp man has to size warps to 50 per cent. increase on grey weight with starch, china clay, etc. The resulting warps are very liable to dust off so that he frequently has to

board off a special section in order to avoid soiling other material. This weighting has not the least influence on the wearability as all the size and weighting come out in the washtub. Who is deceived by this weighting? When common sense reigns in the textile trade this will be one or the practices which will cease.

From the point of view of colour fastness it must be generously admitted that the dyestuff manufacturing industry has played its part admirably in making it possible to colour fabrics so that their wearability fits their purpose. Nowadays there are very few gaps in the groups of dyestuffs which are available for the various fastnesses demanded by the textile trade. One need only mention in this connection the vat and azoic dyestuffs for cotton, linen, and viscose rayon, whilst the British dyestuff industry leads the way in the production of dyestuffs for the successful dyeing of the newest fibre acetate rayon. May I here interpolate this thought. I always think that it was a thousand pities that the basic dyestuffs were the first group of synthetic dyestuffs put on the market. Basic dyestuffs combined a brilliance of hue with a deplorable lack of fastness. Now the brilliance of hue has never been forgotten in the textile designers' studios, but the lack of fastness has been forgotten. The result is that after 37 years in the dyeing industry I am repeatedly having to return a basic pattern and say that it cannot be given fast to bleaching or suitable for casements. Caledon jade green did ease the situation but such outstanding colours are discovered infrequently.

It is to be deeply regretted that although the dyestuffs are available to enable a satisfactory wearability from the point of view of colour fastness to be given many buyers refuse to pay an economic price for their production, so that inferior dyestuffs have to be substituted to the detriment of the wearability. Fabrics of high resistance to light and washing may be produced at a price which many manufacturers refuse to pay. One result is that casement fabrics of inferior fastness to light and washing are coming on the market in increasing quantity. One cannot mention casement curtains without raising the vexed question of the misuse of the word "fadeless." I have demolished its misuse to my own satisfaction more than once in public discussion. I think that everybody agrees—even the greatest protagonists of the fadeless guarantee—that no such thing as a fadeless dyestuff exists. The dyestuff manufacturers with admirable consistency refuse to guarantee the fastness of their dyestuffs, but the dyers continue to do so; moreover, they are increasingly degrading this guarantee by using direct cotton colours which every cotton dyer knows are not comparable—with but few exceptions—to the best vat dyestuffs. The usual defence put forward claims that it is a selling point—naturally the merchant presses for the guarantee so long as the dyer is fool enough to give it—and that it is a question of expediency. Expediency may be defined as a polite description for a sacrifice of principle to gain a temporary advantage. Casement curtains to be usable require to be dyed with dyestuffs which do not accelerate the photo-degradation of the fibres. All fibres are susceptible to photo-degradation—natural silk being the most sensitive. It has, however, been established by several workers that certain vat dyestuffs do accelerate this photo-degradation. A list of these dangerous vat dyestuffs has been published by agreement and anybody who continues to use them cannot plead ignorance.

Dermatitis is connected with the wearability of textiles and until idiosyncrasy is accepted by the Courts as a defence the suppliers of textiles may rightly consider themselves to be placed in an unfair position. A patient may die due to treatment with a drug by a qualified medical practitioner. If the practitioner proves he administered the drug according to the latest medical practice the death is accepted as due to the idiosyncrasy of the unfortunate patient: no blame is attached to the doctor. The supplier of a textile towards which some subject is idiosyncratic is placed in another category. He is held liable for compensation even though two qualified analysts testify that the garment was normally dyed according to the best current practice. Fortunately medical opinion is becoming much more definite on its causation, which opinion must finally influence legal decisions. The following is an extract from an article by Dr. Ingram in *The Lancet*, p. 239, issue 3/8/35 :—

> "No clinician could seriously suggest that the reaction of fabric dye-dermatitis was not due to idiosyncrasy. The clinical evidence in support of this is abundant . . . ."
>
> "Dye-dermatitis like plant dermatitis or light dermatitis is exactly analogous to urticaria produced by sensitisation to eggs, or asthma resulting from sensitisation to roses. Most medical authorities probably appreciate this, if they do not always preach it ; but it would mean the saving of enormous sums of money, of invaluable time, and of much unnecessary ill-health if legal authorities could be persuaded to accept it."

In order to lighten the lament about the deplorable degradation of the wearability of fabrics which has taken place during the years of depression several new processes have been introduced which may be acknowledged as definite improvements in the wearability of fabrics.

The Tootal process of making fabrics crease-resisting by incorporating the new synthetic resins in the fabric structure has clearly filled a gap in the wearing properties of fabrics. Curiously enough I think one of its most successful commercial applications has been on the men's side rather than on that of the ladies'. I refer, of course, to its very successful commercial application to men's tie-cloths.

I feel I shall not be considered rash if I express the opinion that the intensive work which has been and is being carried out as evidenced by patent specifications must finally result in many new and favourable applications of the fundamental basis of the process. Synthetic resin is so new an industry that progress must be inevitable.

Trubenised collars are now a commonplace line in men's outfitting shops which clearly shows that this development has satisfied a demand for ease of washing without the subsequent starching: again it is to be noted that it finds its chief commercial application in the men's wear section.

Shrinking has been one of the great defects in the wearability of fabrics. Who amongst us has not at some time or other been half-choked with a soft collar. Now the Rigmel or Sanforising process (two minds with the same thought) has made it possible for unshrinkable fabrics of vegetable fibres to be produced.

Recently A. J. Hall announced a new process for making woollen garments unshrinkable for which superior results are claimed over the established chlorine process.

Finally the rapid development of the so-called auxiliary products, when one discounts the absurd claims which were made for many on their introduction, is making it possible for fabrics with superior finishes to be put on the market.

THE SERVICEABILITY OF FABRICS IN REGARD TO WEAR. TESTING FABRICS TO FORETELL SERVICEABILITY.

By F. T. Peirce, D.Sc., F.Inst.P., F.T.I.

(The British Cotton Industry Research Association)

When one has to direct discussion to a given subject it is essential from the first to make sure of the meaning of the title. On consulting the Shorter Oxford Dictionary, I found a most formidable list of varied meanings of the little word "wear," among which two may be taken as most pertinent to our Conference: (1) "The action of carrying on the person," (2) "The condition of being gradually impaired in quality by friction . . ."

Imitation Wear Tests.

On consideration of the literature on " Wear Testing," it appears that the textile technologist has a conditioned reflex to the word " wear " that sets him automatically to the design of a machine to grind a hole in cloth with emery. Great care may be taken in the design of devices to ensure control of pressure, speed, condition of the surfaces, etc. but the essential action remains simply the grinding of a hole with emery. The result is obtained—this fabric shows a hole after 100 rubs, that after 120 rubs. And so what? Will the latter prove more serviceable than the former in wear—carrying on the person—or be impaired less in quality as a lining, cuff, furnishing, or what not?

Early in my experience of testing, I met the problem of the wear of varnished healds. Fortunately, two samples were available of which the relative serviceability was well established by use on looms. Tested by rubbing against emery, the more serviceable wore to fracture more rapidly. Its superiority in practical performance lay in its hardness, a quality which protected it from abrasion by cotton and size, but did not avail against emery. Emery is so much harder than cotton or varnish that these cannot effectively resist it. Softer materials may thus suffer less abrasion simply because they resist less. It is more difficult to cut, with a sword, a down pillow than a hempen rope.

Microscopic examination of cloth rubbed against emery or carborundum shows the lesions of the hairs to be tiny, clean cuts. The emery surface itself is seen to be covered with cutting edges as keen as razor blades, and harder. Macroscopically, one might match the emery grinding test with a disc carrying safety razor blades set in its periphery. This might be used to test railway carriage furnishings on a route frequented by schoolboys—but would a higher result in such a test really indicate a higher probability of deterring the proud possessor of a new knife?

The idea behind the usual " wear test " is no doubt that like causes produce like effects on like materials. In use, fabrics develop holes: grinding with emery produces holes and may therefore be used as a test of behaviour in use. But the similarity between the causes and effects, despite the common feature of the hole, is not sufficiently close to warrant any assumption of similar behaviour in use and test. Many holes in worn garments have been examined at the Shirley Institute and none at all like those produced by the usual kind of " wear test " against emery. This might be regarded as a reasonable imitation of the process of sueding, but its bearing on serviceability is dubious.

Many other kinds of tests have been devised to imitate the deterioration of fabrics in use—imitations of kicking holes in carpets, weathering of hangings and tent material, bursting of wounded aircraft fabric, loss of strength, weight, length or colour in washing or use. One may make a routine of devising tests for the endless variety of uses to which textiles may be put. Even the usual tensile test may be regarded as an imitation of the conditions of use, intended to foretell probable serviceability.

It may sometimes happen that a strip of fabric is subjected to a steadily increasing tension till it breaks, but it must be admitted that this happens more frequently in a testing laboratory than in wear. One does not normally use 2-inch wide strips with frayed edges to carry loads. On the other hand, ability to withstand tensile stress is undoubtedly a feature in serviceability, one needs a test for it and cannot imitate slavishly the endless variety of ways in which tension may be imposed on fabric in use.

Most fabrics which fail under tension are not brand new but have already deteriorated in strength through use, by the action of light, friction, washing and general knocking about. However perfect the measure of tensile strength of the new materials, that is not a sufficient measure of serviceability. The various destructive agencies co-operate and a truly imitative test must combine them as in use.

Some of these destructive actions are extremely slow. Even under normal storage conditions, chemical deterioration proceeds continuously. A common test for " ageing " consists in measuring the strength before and after a heat treatment. It is a big assumption to make that this will foretell the deterioration in years of careful use, say as wrapping for a mummy intended to last till the end of the world, or in protected insulation. In a complex of chemical reactions, the temperature co-efficients may vary, so that the relative rates of deterioration of two fabrics may vary with temperature. Yet it is imperative to speed up some actions a thousand-fold to make tests practicable, and heat ageing is the simplest of these.

Serviceability is not concerned only with the formation of holes in the fabric. A collar that strangles its wearer is no longer serviceable, however intact ; baggy trousers are not fashionable nor are the seats thereof intended to warn oncoming traffic. Of these features distinct from strength, length is perhaps the simplest but the imitative test of shrinkage provides pitfalls enough. One specified test defines conditions which do not ensure thorough wetting, so that a waterproof finish would help a material through the test, though it would not prevent shrinkage in continued exposure to damp conditions. Actual laundry machines are sometimes used, with the idea that thus the test is put beyond dispute. But actually, the shrinkage is not at all sensitive to details of the machinery, so long as the material is thoroughly wetted out and given a fair amount of mechanical agitation. Small details of the procedure of drying and pressing are more important. Nor is the percentage shrinkage a direct measure of serviceability. A test to produce maximum laundry shrinkage may produce a slack fabric easily capable of being stretched back 1 per cent. to its original dimensions: another fabric might shrink only ½ per cent. but resist re-stretching and cause trouble as a hat or shoe lining. On the other hand, stretching may cause bagginess and affect serviceability. It would be quite unreasonable to suppose that the result of any one general test of shrinkage can determine immediately the serviceability of fabric in regard to the stability of dimensions in use.

In one important instance, the specification of a minimum of shrinkage on wetting actually had the effect of increasing the trouble due to shrinkage in use, which was really the shrinkage of the weft dimension of tentage, due to stretching of the warp.

One might continue beyond all patience in pulling to pieces the numerous imitative tests constantly being put forward—and scrapped. The title of this paper is itself, in one possible sense, indefensible. Though the ultimate object of testing may be to foretell the probable serviceability for a particular purpose, the test result itself cannot be taken immediately to constitute such a prediction. The world of practice presents to mere imitation a bewildering, overwhelming complexity. The diversity of conditions encountered by individual garments would make of little account the results obtained in any arbitrary combination of destructive agencies. The long working life of garments makes it imperative to accelerate the destructive action, and to do this without changing the essential character demands more than outward imitation.

A valid imitation of service could be devised only after a thorough survey of the behaviour in use of each fabric—analytical to determine the nature of the causes and effects of deterioration, statistical to determine their relative importance. But when such a survey is made, better use can be made of it than the design of an imitative test. Weak features can be corrected and economies made at the expense of the strong, so that the imitative test would no longer be valid.

A holiday tent of flax canvas used, on account of its weight, to need a mule for transport. After a study of performance in the field, it was found that the heavy stresses could be put on a frame of tapes and the walls be made of the finest waterproofed cotton material, so that good service is obtained with a weight suited to a rucksac. Serviceability depends on making-up as well as fabric manufacture, in regard not only to the duration of useful life but also to the features that cause failure.

In short, imitation is no substitute for understanding. It is a short cut that leads into a bog of false appearances and culs-de-sac. This does not mean that testing is futile, but that its function is not mere imitation. The function of science is not to reproduce the world in miniature in the laboratory but to pierce through the outward complexity to the essential simplicity, to understand. The direct purpose of a test is not to tell fortunes but to determine characters.

Character as Index of Serviceability.

That character determines behaviour is the faith of science, that character is known only from behaviour is the essence of its method ; and the relation between character and behaviour is its way of progress. Behaviour is the interaction between character and environment. If the environment is simple, constant and known, the behaviour of objects therein indicates their character. From the known character, the behaviour of an object in any environment may be deduced, in so far as the pertinent facts and relations are known. Character is not a mystic " thing-in-itself " but a figment of the mind, a device to co-ordinate experience of behaviour. This co-ordination, and not imitation, is the purpose of science.

This may seem an abstract approach to the study of kicking a hole in a carpet, but the deterioration in service of a fabric is a most complex phenomenon. The method of study needs more critical consideration

than such simple matters as counting neutrons and measuring nebular distances.

According to these principles, the scientific approach to our problem would be (*a*) on the one hand, to determine the character of a fabric : that is, to observe its behaviour under simple, known and constant conditions : that is, to devise and apply tests—*not* " wear tests " but tests of staple, structure, strength, resistance to abrasion, etc. ; (*b*) on the other hand, to analyse behaviour in service to determine the destructive agencies, the effects they produce and their relative importance, (*c*) then to correlate the measured characters with the effects produced by the several important and essential types of destructive action.

In the present state of the subject it does not seem possible completely to correlate behaviour in service with the simplest characters alone—structure and chemical composition. Hence we must accept direct tests of more complex behaviour, strength, resistance to abrasion, etc. These should, however, be designed as tests of character, with simple conditions idealising the essential types of destructive action, not complex combinations of arbitrary features trying to imitate the accidental circumstances of practical use. Their results should not be accepted as measures of serviceability but as complex characters, to be correlated empirically with structure, etc. on the one hand, with experience of service on the other. Even then, the simplest tests should be used to their limit, calling in the more complex only when they prove insufficient.

It seems to me that the sound scientific method and the best practice agree on this point, as they so often do. Imitative, complex tests of serviceability are not much used by practical technologists ; they rely rather on staple, cloth structure, weight, percentage of loading material, and judge from these characters on the basis of their practical experience. Testing is a development of the hand and eye ; not a substitute for expert judgment but a tool in its service.

Regarding tests as measurements of character, the results do not in themselves give information on serviceability. They must first be correlated with experience of service. Quantitative surveys of the deterioration in use of garments are difficult to carry out, but the prediction of serviceability must contain a large element of guess-work till they are made. It is difficult to gain significant information on the behaviour in use of lines that change in quality. Standardised lines, especially when regularly supplied to large institutions, promise the easiest field for effective statistical treatment. In the meantime, one must rely on general experience and the examination of random samples of goods in service, including complaints arising in commerce. Actually, though unsystematic, such experience is by no means negligible and much useful work is being done on that basis with the imperfect set of character tests and theoretical analysis available.

This unsystematic body of knowledge is sufficient for the correction of isolated features that produce distinctive types of failure. Of two samples one was found to wear out more quickly than another. They proved identical in structure, save that the former had a larger proportion of short fibre. This provided an obvious explanation in accord with the appearance of the frayed yarns, and an obvious method of improvement. A semi-stiff collar cracked at the fold and an analysis of structure suggested modifications that provided more " give." Undue weakness of white goods is often shown

by fluidity to be due to overbleaching. This is a good example of the character test, for the measurement of the fluidity of a solution of cotton in cuprammonium could not be farther removed from an imitative test of disruption, but no test is of more general value.

Complex Characters.

Following the experimental method, one deliberately produces materials identical in all particulars save one, measures the characters of the experimental products and observes their behaviour in service. Here lies the difficulty that forces one from the straight and narrow path, for the accidental circumstances of ordinary service are so varied and indeterminate that statistically significant results are very difficult to obtain. Tests intermediate between pure character tests and service trials are necessary to minimise the time, cost and uncertainty of the latter, to supplement the insufficient data of the former.

Such tests are a compromise, full of danger of implicit, unjustified assumptions; but this is minimised by regarding them as "complex character tests" rather than as "wear imitation tests." The difference is one of orientation and interpretation rather than of mechanical detail. The emery grinding test might be regarded as a complex measure of thickness, modified by the coarseness of the fibres and yarns, the levelness of the fabric surface and the hardness of the structure. Empirically, it might be found to have some correlation with the wear of some fabrics for some purposes—possibly small boys' trousers in the Millstone Grit area—but that has to be demonstrated. There are insufficient grounds to claim that the results rank fabrics in regard to serviceability, relying on the imitation of service conditions.

Among the endless variety of complex character tests conceivable, one seeks those that, on the one hand, may be logically related to structure or simple character tests and, on the other, will yield high correlations with behaviour in many and important types of service. The ability to devise such tests is enhanced, on the one hand, by the development of the fundamental theory of cloth structure and behaviour, on the other, by analysis of service experience to determine the essentially simple types of deterioration and of the agencies productive thereof.

It is not possible in this paper to enter in any detail into the connected story of investigations of various problems of serviceability. Some of the points of the discussion may be brought out by a mere recital of a random selection.

Wearing into holes, and threadbareness of shirts, sheets, hose, rubbered raincoats, upholstery, overalls for uses from clerking to sand-blasting.

Tearing at seams of overalls, etc.; fraying of limbrics and sateens (slipping of threads at seams or by rubbing).

Creasing and resultant abrasion.

Loss of pile of velvets and of nap of flannelettes.

Roughening and loss of lustre in sateen linings.

Shininess of gabardines.

Loss of shape: shrinkage of shirts and overalls, sagging of rayon vests, shrinkage of hangings and blind-tapes, stretching of corsets and hose, change of shape of waggon-covers and tent canvas, loss of tautness of doped aircraft fabric, stretching of spindle-bands, shrinkage and bursting of shoe-linings. Puckering of seams. Curling of book covers.

Weathering, mildew attack, abrasion and tearing of canvas in tents, seats, tree covers, etc. Changes of permeability and water resistance.

Failure of tyre reinforcement.

Heat tendering of calender covering, filter cloths, electrical varnished cloth, oiled rainproofs. Electrical breakdown of insulation after a period of service.

Light tendering of curtains.

"Wear" during processing: abrasion of warp in weaving; holes, cracks, tears, weak spots and marks caused in weaving, cropping, singeing, calendering, beetling, raising, bleaching and by accidents of all kinds in manufacture and use.

Obviously the various fabrics listed here could not be ranked in any one order of "Resistance to Wear," judged by any one criterion of damage, produced and measured by one method—nor by two, three, four or a dozen. Occasionally, one must admit, it seems that one can devise a machine to imitate service truly and yield a figure acceptable as a comparative measure of serviceability. A brake lining might be tested thus under conditions of actual service. But that is just the point—conditions of actual service. It might be done in a laboratory, but it is a practical trial rather than a measurement of a quality. In general, the conditions of actual service cannot be truly reproduced in the laboratory. Practical service trials might be controlled and intelligently simplified to yield useful results more quickly than a statistical survey of uncontrolled consumer use. They would have to be devised carefully for each particular purpose and they are undoubtedly useful—drop tests for parachutes, road tests for motor tyres, the tailor's try-on for the fit of a suit. Such experiments become very complex for most of the problems listed above, and are hardly what is usually meant by "wear test."

A perusal of the list of problems may suggest other principles which were emphasised by the investigations:

(*a*) Fabrics, or one and the same fabric put to one use, may become unserviceable through failure of a variety of features.

(*b*) Present knowledge is insufficient to deduce serviceability from simple character tests alone, in any general way.

(*c*) Many failures occur through the combination of several causes which conspire with each other.

(*d*) A few types of destructive action can be detected, which are of frequent importance and of relatively simple character, if separated from accidental concomitant actions.

Coherency, with Tension and without.

The upshot of the discussion is that we must accept the necessity for tests of resistance to destructive actions of various kinds, which are not immediate measures of simple characters but integrate the resultant effect of a combination of these characters on resistance to some definite and simple type of external action.

The most familar example of such a test is the tensile test for strength. Regarded as an imitation of the breakdown of a fabric in use, it is open to severe criticism on many points; but regarded as a test of character, supplementing structure tests, it gives information on the coherency of the fabric that is of undoubted value. That value depends more on the intelligent

understanding of the effects of tension and on empirical correlation with service than on details of mechanical similarity between use and test.

A cotton fabric is like a well-made knot—the harder it is pulled, the stronger it becomes. The twist in the yarns and the crimp of the threads resolve the applied load into normal forces which strengthen the cohesion* between the fibres. But in wear, there are other factors that attack the coherence of the structure, and more subtly. It may be dissolved, cut or teased into disruption. The many forms of " wear test " seem to owe their existence to the realisation that the character of coherency against tension is not the only feature necessary in a fabric to withstand wear. Rather than devise endless imitations of wear, it appears, however, more fertile to enquire what these other features are and to devise tests for them.

Probably the most important of such tests is that needed to determine the coherency of the fibres when not held together by external tension, against forces that tend directly to disturb their arrangement in the cloth structure. This coherency depends on the surface and dimensions of the fibres, twist and counts of yarn, closeness and crimp of threads—a complex combination of structural features but resultant in a fairly definite character of the fabric, no more arbitrary than tensile strength. The behaviour in use most directly related to this type of coherency is resistance to abrasion —not to cutting actions, but to rubbing to and fro that tends to drag the fibres apart by friction and break them only one by one as they become isolated. This is like the untying of a knot by a neat-fingered woman, where tension is like a strong man tugging at it.

Other factors in use that tend to tease the fibres apart and weaken the structure are oscillations of tension and bending, which cause the fibres to move relatively to each other. Abrasion tests are sensitive to the microscopic form and chemical state of the surface, so may usefully be supplemented by other disintegrating tests. It would be inappropriate in this general discussion to describe the particular methods used to test these aspects of coherency.

Sharp bending may disrupt the fibrous or other material itself, in a brittle fabric, such as starched, oiled or doped fabric or cloths with yarns of bast fibres. A " Cracking Test " is a useful addition to the resources for studying such materials—a strip of say varnished fabric is held in a grip with nearly sharp jaws, with a moderate load ; the jaws are oscillated till the fabric fails. Fails ! In what way ? It may crack and tear, but that is an extreme effect of bending and not necessarily the only way in which material may become unserviceable. It may become unsightly with permanent creases, or lose its waterproof quality or resistance to electric discharge.

Quality Tests for the Condition of Unserviceability.

So far we have considered mainly the disruption of the fabric with the formation of a hole or tear, and there can be little dispute that this represents an unserviceable condition. But many a garment is discarded without such indubitable evidence of wear ; the character has changed so as to render it unsuited to its purpose. Here enters another function of testing, again to test character, but as a measure of quality rather than behaviour. It is implicit in the destructive tests, the quality of wholeness being so obviously

* "Cohesion" here means the force that makes the fibres cohere, " coherence " is the condition of having a coherent structure and " coherency " is used to denote the quality that maintains coherence.

distinct from disruption. Generally, however, the unserviceable character must be demonstrated by test—simple, as in length measurements for shrinkage or subtle and complex, as in changes of lustre or colour.

When the end-point is not obvious, as in disruption, the method of expressing the result of a test of gradual deterioration comes into question. The easiest method is to impose a certain amount of treatment—rubbing or what not—and measure the quality of importance before and after. If, however, the quality measure corresponding to the unserviceable condition can be determined, it is more to the point to determine the amount of treatment necessary to produce this condition. This method of expression is also simpler, less arbitrary and more suitable as a basis for comparison of materials, than the change of quality produced by an arbitrary amount of treatment. The treatment necessary to make the material unserviceable may be called the " useful life " in the test and may be correlated empirically with the " useful life " in terms of hours of wear or some such measure of survival in service trials. Thus, the number of bends in a cracking test, which make an oilskin permeable to water, may be determined; or the number of rubs necessary to produce unsightly hairiness on a sateen lining.

To determine the end-point of the test, it will, however, be necessary to give a graded series of treatments and obtain the curve of the quality measure against amount of treatment. This is more laborious than giving one standard treatment, but the fuller information is usually worth while. A general relation may be indicated, and then two or three points will suffice to determine the whole curve. Such a relation has been found between heating and fluidity (or strength) of cotton materials.

The appropriate quality test or tests must be determined by service trials or surveys, being devised to test the features most liable to fail in service and of most importance for the purpose of the material. The measure or test result corresponding to the unserviceable condition must also be determined empirically, by tests on worn garments. An indefinite variety of quality tests may be used in conjunction with durability tests—visual or microscopic examination for disruption or for judgment of appearance (loss of pile, discoloration, creasing, "fraying" or slipping of yarns, etc.), length measurements, measurements of weight, thickness and compressibility, stiffness, lustre, friction (for hairiness), air permeability, water penetration pressure, strength, fluidity, electrical breakdown voltage, etc. All these and more have been used at the Shirley Institute for practical studies of serviceability of a wide variety of materials for varied purposes. Any quality test worth while doing on a *new* fabric may be pertinent to the judgment of serviceability of material subjected to a destructive test such as abrasion.

Condition during Service.

The end-point at which a material must be discarded is not, however, the only measure of serviceability. The quality of the brand-new cloth is of interest, the duration of its useful life also, but its quality during the period of service is surely pertinent also to its serviceability. One fabric may maintain a moderately high quality with little change for a long period; another may be made up to an excellent condition on the counter but lose this excellence almost immediately, though remaining serviceable for an equal period. This is one reason for the superiority of the curve mentioned

above over the test by one standard amount of treatment or the determination of end-point only.

It also raises the question of the interaction of different factors of deterioration. Destructive wear produces most of its effect on fabrics which are not new. What is the use of observing the resistance to oscillating tensions of a shirting filled with starch, if it is to be washed after a few days' wear and never starched again ? Rubbing is much more destructive on cloth tendered by light, etc., than on the new material, and the extent of this interaction depends on structure. Changes in dimensions, crimp and lubrication which occur in service affect resistance to tension, bending and rubbing.

This consideration may seem to be leading us back to the complex, imitative wear test. It is possible, however, to avoid that cul-de-sac, combining the actions but keeping the variables separate, so that the different features may be separately evaluated. Pre-treatments may be given to reduce the cloth to the condition in which most of the destructive wear is suffered. Tests on used white overalls indicate that this condition may be described as fully shrunk, lightly starched and ironed, with a fluidity of 20. This condition may be produced by simple and controlled treatment, without complicating the procedure or interpretation of tests by tension, rubbing, etc. It is, in fact, a simpler and more definite condition than the commercially finished state.

The conditions of the actual durability test may also take account of conditions of service, without degenerating into complex and arbitrary imitations. If a garment, such as a woollen overcoat, is weaker and more severely treated in service while wet, a test in the wet condition is more pertinent and no more complex than in any arbitrary moisture condition. If tensions, direction of rubbing, etc., in service are determinate and known, these conditions may reasonably be reproduced in a rubbing test. In so far as conditions of service are unknown and are yet influential on the test result, the element of guesswork enters. Choice of conditions is no grounds for claiming the test result as a measure of serviceability ; it is justified only by its fruits—a higher correlation with service trials—and this needs demonstration.

Statistical Considerations.

A discussion on textile testing would be incomplete without a word on variability and statistical considerations. Resistance to destructive action is sensitive to many features that commonly vary from place to place in a piece and from piece to piece of nominally uniform cloth—counts, twist, threads per inch, crimps, etc.—and the effects of these normal structural variations must be allowed for by normal good practice in sampling and analysis. Beyond this, however, the serviceability of a garment is also subject to the " weakest link " principle. If all the garment is intact save for one place that develops a hole, many users will regard it as past service. In sampling material for test, it would be most dangerous to attempt to seek out the warp smashes, setting-on places, slubs, etc. which might prove points of weakness. The obvious ones might, in any case, be eliminated by a good maker-up and hidden points of weakness may exist—partial lesions made by shuttle tapping, heavy schreinering on hard spots, singeing at open spots, greasy spots or what not.

Gradual disintegration is a slow business and such tests as abrasion cannot safely be made very drastic. They must therefore be concentrated on small points of the fabric and cannot pick out infrequent weak places, which may be ruinous to serviceability. They may be used to assess the value of normal structural features—the importance of twist, staple, lubrication, etc. —in a fabric but may not safely be used to rank actual samples in the order of their future duration of service.

In the interpretation of a set of tests in regard to serviceability, the "weakest link" principle again enters. It is the feature that fails first that determines the useful life; the identity of this, and, therefore, the pertinent test, will differ with different fabrics, making-up and service conditions. A general averaging of results of a set of tests to give a measure of serviceability tacitly assumes that the fabric will remain serviceable in every way and part, till at some moment it ceases to be—an awkward contingency for apparel from which the imperfections of textile technology will long save us.

A simple example of this point is found in the breakage rates of warps, which show a minimum at a certain percentage of size. Tested by rubbing, the warps show rapidly increasing resistance as the size is increased from low values, with little but still positive effect at higher values, *i.e.*, no optimum value. But the extensibility shows a reverse effect and the optimum in weaving may be ascribed to the change over from abrasion to brittleness as the feature productive of breakage. Probably the most fertile application of testing in regard to serviceability is not in foretelling duration of life but in correcting weak features.

It would, of course, be impossible to foretell the duration of an individual garment, but that constitutes no real difficulty. In commerce, the factor that determines success is the profitableness of the whole production of a line of goods; even the individual customer cannot hope to be guided by anything more definite than the probable duration of the garment in the use intended. Scientific technology cannot and need not claim to predict individual histories —it is concerned with statistical quantities. There remains, however, a formidable task in predicting the serviceability of a material, after complete testing, in conditions fully known, in terms of statistical duration of useful life.

This demands (*a*) a statistical description of the probable conditions of use in measurable quantities, including the influence of making up on the localisation of damage and on the importance of the several characters, (*b*) a statistical description of the characters of the material, including the probability of local weaknesses, (*c*) the determination of the quantitative effects of known characters on useful life under known conditions, taking into consideration the fact that the useful life is ended by the first essential quality to fail, under any form of destructive action, over any considerable area of the garment.

The essentially statistical character of any sound interpretation of destructive tests emphasises the importance of the statistical analysis of the results thereof. The form of the distribution may be far from normal, and that will affect the probability of very weak places; it may be normalised by transforming the results into an appropriate form, using instead of "number of rubs, n" some other function, $1/n$, log. n, etc. The effects of any arbitrary features of the test should be determined by known variations of pressure, speed, direction of rubbing, area, tension, abrasive, etc., in a

rubbing test for instance ; also the effects of known variations of structure, counts, twist, crimps, etc. such as may occur in practice. The variance of the test results should be analysed to determine the amounts due to variations in test conditions and in the material.

We may conclude that the scientific determination of the serviceability of a fabric is not possible. If we mean a precise and certain determination by a perfectly logical method, that admission of frustration must be allowed. But such a determination is only an ideal towards which science strives and which scientists never attain. The imperfect results of scientific progress are impressive enough and we need not despair because we are not in this matter in sight of perfection. What, however, we should do is to realise what inexact, uncertain and illogical methods we are using, claiming no more for them than is their due, rejecting their evidence when it is found to be outside the necessary limits of uncertainty or contrary to more certain evidence, and mercilessly criticising ourselves and each other.

In conclusion, I owe my audience an apology. My remarks have been somewhat provocative and fully deserve a spirited counter-attack. To this I will give an attentive ear but necessarily a dumb tongue. These thoughts arise from a long and varied experience in the subject, but the subject matter has been the problems of concerns whose interests I must not betray. I cannot, therefore, give the practical details that would support my points with effective instances and add interest to this rather boring sermon of generalities. Nor can I add to this critical introduction, the constructive exposition of the principles put forward. That demands statistical surveys of service, of prime importance to those commercially concerned, and a continuous development of theoretical studies, on the lines of the recent "Geometry of Cloth Structure" (*Shirley Institute Memoirs*, 1936, XV, pp. 65-116). The "Analysis of Shrinkage" therein may be instanced as a simple example, to be contrasted with that interpretation of a shrinkage test, which would make a certain result the automatic criterion of unserviceability, irrespective of the cause of shrinkage or use of the material. The simplest example of a thorough investigation into the serviceability of any one kind of fabric would demand a long Memoir. No testing machine, however intricate or ingenious, can show on its dial an answer to such problems ; it can only be a tool in the hands of a trained man, on whose judgment the value of testing depends.

SUMMARY.

Imitative tests are a delusion and a snare. Tests should be devised to measure characters, defined by behaviour under the simplest possible conditions. Their validity depends not on imitative features in testing procedure but on intelligent interpretation, based on empirical correlation with service experience.

In the present state of the theory of cloth structure, it is not possible to bridge the gap between simple tests of structure and behaviour in service. Hence arises the necessity for complex tests, but even destructive tests should be devised to measure definite characters and be justified empirically.

If statistical surveys of service are impracticable, observation of consumer use may be supplemented by simplified service trials, reproducing the actual conditions of service. Generally, a valid service trial would be impracticable as a laboratory test.

Strength is a character so complex and so important that direct tests are necessary. The tensile test is insufficient as tension itself contributes to the cohesion. Supplementary tests are necessary for resistance to disintegration by abrasion, bending and oscillating tension. The microscopic cutting action of emery is not a suitable test for this character of coherency.

Disruption is not the only ground for unserviceability. Loss of other qualities may end the useful life of a garment. Tests for these qualities are necessary to gauge the effect of a destructive test and relate it to effects of service. The commercially finished state may not be the most suitable for tests by destructive actions. The material may be brought by pre-treatment into the state in which it suffers most wear. Conditions of the tests may also be chosen, without complicating them, to correspond to conditions of wear, so that correlation with service may be improved.

Test results are not direct measures of serviceability. They must be interpreted statistically, by trained judgment resting on the twin bases of theory and experience. Statistical considerations almost preclude the fine ranking of actual samples for serviceability ; testing finds an easier and very fertile field in the correction of weak features in cloth structure and make-up of garments.

THE JUDGMENT OF FABRICS

By HENRY BINNS, F.T.I.

Dr. Peirce is to be warmly congratulated on his admirable survey of testing methods and for his candour in stating his case impartially. May I refer to a few points which concern my own outlook. He states that "practical technologists rely on staple, cloth structure, weight, percentage of loading material, and judge from these characters on the basis of their practical experience. Testing is a development of the hand and eye, not a substitute for expert judgment but a tool in its service." And later, "The simplest example of a thorough investigation into the serviceability of any one kind of fabric would demand a long Memoir. No testing machine, however intricate or ingenious, can show on its dial an answer to such problems; it can only be a tool in the hands of a trained man, on whose judgment the value of testing depends. Imitative tests are a delusion and a snare. Tests should be devised to measure characters, defined by behaviour under the simplest possible conditions. Test results . . . must be interpreted statistically, by trained judgment resting on the twin bases of theory and experience. . . . In general the conditions of actual service cannot be truly reproduced in the laboratory."

Dr. Peirce frequently makes use of the words "numerous" and "complex," and states that these factors must be correlated statistically to be of scientific value. He definitely gives judgment the first place and rightly so, for "the accidental circumstances of ordinary service are so varied and indeterminate that statistically significant results are very difficult to obtain."

What is Judgment?

Buying and selling involve the judgments of the people concerned and in the case of textiles include the interpretation of impressions by the senses of sight and touch. Wear may be more important than appearance and handle; in other cases it may be a distinct disadvantage, as in ladies' dresses, owing to fashion changes. This is neither the time nor the place to discuss the theoretical characteristics of judgment, but it is desirable to draw attention to a few salient points. When human beings are involved, uncertainties must exist. To the numerous and complex factors which enter into material considerations, it is necessary to add the words "irregular" and "fluctuating," in dealing with judgment, owing to its inclusion of emotional tendencies in a complex nervous system.

The immense difficulties arising in these circumstances must be obvious. Individual preferences must be allowed for. Psychology is now attempting to foretell what the serviceability of a boy or girl is likely to be, just as we are attempting to define the serviceability of fabrics. Of the two, I imagine the latter to be the more probable because of the immeasurable features and the unknown environment connected with human beings.

The advantages in the use of judgment lie in the ability to sum up rapidly in one decision a great many facts and preferences. The experience of the past can be used to compare these and to form an estimate of the future. In the case of greasy wool, for example, a decision may be arrived at to cover yield with astonishing accuracy. The fineness, softness, length and other characteristics, all of which come under consideration, help to fix the price limit in one operation. Prof. Bartlett has recently stated that "quite

a lot is known about the cutaneous reaction of each quality of touch taken by itself, extremely little is known about the massed response of the cutaneous mechanism to the combined qualities when they are produced together." The word "handle," as we know it, is, of course, infinitely more complex. The co-operation of the eye and the hand offers another significant but unknown factor. The irregularities of wool fibre diameters as seen by the eye are averaged into a quality decision with remarkable accuracy. Just as different types of measures are used for solids, liquids and gases, so, I believe, is judgment the most suitable and the most accurate measure when the factors are numerous, complex, irregular and fluctuating. The "obvious" is recognized as being almost impossible to explain. The word "judgment" is understood by everybody and yet, from our standpoint of technology and science, relatively little is known.

Empirical Judgments

Instead of regarding sections of the trade as in horizontal or vertical sequence, let us examine them as duties of individuals divided roughly into those who act on judgment and those who are engaged in processing. The wool buyer at the London Wool Sales offers a notable example for the exercise of judgment. He has to select from a wide range of varying types with their details and, using all the fundamentals of judgment, bring about a quick decision. Whereas a worsted spinner is limited by the capacity of his machinery to deal with specific types, time is less pressing than that of the wool buyer, and his judgment is refined along narrow, but often subtler limits. The dyer and finisher make a direct appeal to the senses of the consumer by a mass appeal, rather than on fibre characteristics.

The wholesale buyer has the difficulty of estimating his wants, the kinds of cloths, designs and colours suitable to different districts with which his firm is connected. In buying and selling certain tendencies are apt to interfere with sound judgment; the power of "suggestion" should be kept well in hand as well as that of bias. He must be able to weigh evidence. Erratic judgments result from ill-health, fear or excessive optimism.

Many years of investigating leave me with happy memories of thrills caused by unexpected results obtained. Some of these seem impossible of attainment. Indeed, in the last paper of mine published in a scientific journal, the statistical correlations had to be omitted, by request of the Editor, because of their incredibility. The number of errors was snbstituted and, in my opinion, this reduced the essential value of the paper.

Salesmanship is also a judgment operation in the textile trade. Between the processes there is little room for the use of suggestion as buyer and seller are aware of the conditions. The blending of several types of wool in tops leaves a good deal to the imagination, it being unusual to declare their composition. The judgment of all the factors involved in quality is, when impartially carried out, reasonably accurate. It may be that a buyer offers a price on the basis of a "super 60's" and as a seller the same day offers it again on a basis of a "super 66's"; having already decided it is an average 64's. That represents his judgment of individuals and will be modified in proportion to the ability of judgment by others; it does not indicate his accuracy of fibre judgment.

In forming judgments from the salesman's point of view, the prestige of his firm needs to be kept in mind; by doing so the tendency to exaggerate the qualities of his goods is kept within bounds. A buyer's knowledge of

fabrics is usually limited to his experience, some item is generally missing which may or may not be essential in judgment. In regard to appearance and handle, buyer and wearer are mostly able to look after themselves, but as to wear and fadelessness of dyes they may be at fault. Dr. Peirce has pointed out the methods used by the practical technologist. The practical commercial traveller, who is probably no better informed than the buyer, will find ways and means of providing the missing information which the buyer needs, if his judgment is to be sound. That may be " suggestion " of a subtle kind, but actually it is stabilizing judgment by giving essential facts which must come from trustworthy sources.

As a member of the United Commercial Travellers Association for over forty years you may be interested to know how the same point was handled in my early days on the road. Union shirtings were popular and these had Belgian wefts, giving a smart appearance and a soft handle. I practised " thumbing " until it was possible to split holes across a piece rapidly. This method I showed to my customers, knowing that my cloth would bear the strain. At another time I treated a good many yard lengths with different kinds of soap and with varying degrees of severe treatment. These samples were direct evidence that the worst treatment had little detrimental effect on the shirting. Later I sent samples to an official testing laboratory and showed the results of tests to my customers.

In one case the evidence was provided by the customer, in another by myself, and a third by a responsible independent authority. The net result was the building up of a stable connection and a lengthy period of safe and profitable trading. The point of contact between empirical judgments and technical tests is to-day a very live question and concerns the relationship between trade and science. The judgment people being in the vast majority, as they include the general public, will require evidence that physical and other tests are more accurate and more appropriate than judgment in specific cases. These do not displace the need for judgment, but make its decisions much more reliable.

Natural Judgments

Tests conducted with the help of practical men can give no indication of the natural ability on which their empirical or technical judgments are founded. It is necessary to trace developments from those who have not had the opportunity for cultivating judgment by even a small amount of experience, onwards to the expert. I have made it a practice, in carrying out technical tests, to apply the same technique to children and to non-trade adults of both sexes, and to members of the trade. This procedure was considered inappropriate by some headmasters, but the results almost invariably aroused their curiosity and confidence.

May I briefly allude to a few representative cases: 375 children and adults in groups of five examined 30 samples of union shirtings and flannels which had been used by myself, as a traveller. The original scheme was to test experienced people only.

As an after-thought, these exceedingly difficult media for judgment were tried on various classes of people, children of various ages, non-trade adults of different social grades, manufacturers, dyers and finishers and wholesale and retail buyers, in groups of five persons each. The results showed two very clearly marked characteristics—a natural judgment arrived at by the intelligent use of the hand and eye and a technical

judgment based on cloth construction and trade considerations. On one of the tests a cloth which was placed fourth out of five places by experts was the first choice of practically all the children—incidentally it was the best seller in the range. Non-trade adults varied according to experience towards one or the other standards.

It was also noticeable that, taking the children's standard as a criterion, the groups of defective children were graded as at school into good, medium, and poor. The elementary children followed the same course, but the secondary children seemed lower than might have been expected, some sixteen-year old boys, good at book work, being on a level with the good defectives. It appeared that natural judgment calls for the balanced use of hand and eye and of co-operation with " intelligence," as known to psychologists.

Another illustration is afforded by typical Bradford wool tops. It is generally recognised that several years at the board in gaining experience is necessary in order to judge qualities. Carefully-prepared samples, six in number, were taken to an elementary school, where the headmaster supplied five boys and five girls of eleven years of age to undertake an experiment. Fibres were drawn from each quality on six separate small black velvet-covered boards for discrimination by sight for " fineness."

Twelve-inch lengths of each were prepared for selection by touch—the criterion being "softness." Each child then graded the samples six times under controlled conditions and in the presence of myself only. The average gradings were in each case according to the trade standards which shows that in this case the eye and the hand arrived at the same conclusions from totally different criteria. This feature was confirmed with adults and by experts and, on the authority of Professor Bartlett, opens up a new avenue of research in psychology.

Of the five girls, two placed the tops in correct order five times for softness. Another only made two out of a possible 90 errors. Later it was found that middle-aged women could also do the test with none or only a few errors. I have not found such a degree of accuracy in most experienced topmakers, though these did much better on sight tests. The results of a series of tests with people of varied experience seems to indicate clearly that the sense of touch remains approximately the same in an individual in spite of experience, though there is evidence to show that it may deteriorate by the handling of hard—e.g. metal—materials. The most accurate results in a long series of tests upon myself were obtained at the end of a whole day of heavy gardening, when I anticipated a severe decline. Ill-health, however, has disclosed a marked reduction in efficiency on the part of experienced men even though they felt at the time able to carry out the tests satisfactorily. So " staggering "—to use words expressed by business men—are these results that I have suggested wool tops as a medium for the measurement of the sense of touch.

Samples are now in preparation with a view to further experiments in order to discover the breaking point of discrimination.

Men, women, boys and girls who know nothing of textiles, have been able to detect minute differences in cloth construction, some of which it would be difficult to trace by the usual test methods, for example, differences in apparently identical cloths made from wools of the same quality but of different countries of origin, others from the same wools by varied methods

of combing, drawing and spinning and others by varied blends of similar wools. Probably the fact that the technical causes of differences were not known to the subjects resulted in their ability to define something which they could neither analyse nor explain.

I have in my possession a section sample of a navy coating made by a well-known Bradford manufacturer. Seven warps of 64's quality bought from different spinners have been crossed by seven wefts of the same quality but again from different spinners; the counts and turns are alike. The 49 cloths produced show very varied characteristics. There is a wide range of tones due to the origins of the wools and their blends; the handle is equally affected. Slight differences in the clearness of the twill are to be observed.

Only a few of these cloths would be produced and offered to a merchant, and he, in turn, would compare these with cloths submitted by other makers. The retail-buyer would again select from the collection of several merchants. I have evidence that the lady-user has more sensory sensitivity than is commonly supposed. The wearing properties of any of these comparable coatings would not be likely to be questioned.

Price and many other factors come into the selection at each point of transfer. Judgment alone is used; physical and chemical tests are not required. It is obvious that the diameter of the various wools is not the determining factor as all the yarns are sold as the same quality; the chief difference lies in their innate characteristics as demonstrated by the colour and by the handle. In selection, preferences are as important as facts and in this sphere judgment is the only criterion. It seems to me probable that the correlations of the technical, empirical and natural judgments concerned would be high if such a test were attempted.

Some people's judgments are excellent by sight and defective by touch; others the reverse. Just as one eye may be more effective than the other, so one hand may be more sensitive than the other. Though it seems probable that the adjustments of the hands and eyes in judgment are well balanced, a defect in any one or more of the four will upset a correct interpretation of the criteria.

Judgment and Science

We might well consider the following quotation: "Reflective people everywhere are looking for guidance in the maze of thought and practice in which they find themselves. It would be fitting if the required direction were to come from philosophy, whose aim is to see life steadily and to see it whole. . . . In its critical function philosophy points out that the original beliefs of common sense are vague and unanalysed."

Professor Spearman recently wrote that "psychology is suffering to an extraordinary degree from dissentions between its several schools. . . . They have been called, misleadingly enough, 'intuitionist' and 'psychometric' . . . In psychological statistics, the disproportion between the wealth of figures and the poverty of their meaning is often pitiable. . . . The main function of statistics is to verify conclusions reached already otherwise. . . . All discoveries have been surmised beforehand, but out of countless surmises only a few have the good fortune to be verified. . . . This is the great ordeal of science. The trouble with the intuitionists is that by them this ordeal is shirked. . . . The intuitionist tries to make ideas work without

mathematics . . . the psychometrist, mathematics without ideas. When will both learn that two legs are better than either alone ? "

As a buyer and commercial traveller I can lay some claim to know what the average business man feels about intuitional methods. Intuition is placed first of all qualities by many prominent and thinking commercial men. They look with suspicion on the elaborate measurements and statistics of the technologist and scientist. They see a material as a whole, whether it be a mass of wool fibres or a fabric and form an impression on the appearance and handle which determine its suitability and value for their particular purpose. The customer in the shop does the same. Hence from the grower to the ultimate consumer there is a chain of intuitionists or, as I prefer to call their practice, " judgment."

Parallel with the intuitionists are the people who measure and codify their knowledge, usually specialists, who do not see their material as a whole but in analysed parts. Their difficulty lies in summing up the parts into a complete whole. This is especially so in natural textile fibres where there is so much irregularity and so many properties which are complex and fluctuate from time to time as a result of climatic and other conditions.

In trade as in science there are apparently conflicting aims. In reality there is no such division. Judgment is in certain circumstances the only available means, and it is refined by experience and education including science ; ill-health and fear tend to create uncertainty. The accelerator of the growth of judgment is sustained emotional interest ; its control is under the will.

Sustained Emotional Interest

Serviceability is the most important item in such fabrics as uniform and aeroplane cloths : the preferences of individuals play no part. In my early travelling days advice was sought and taken between buyer and seller. To-day, the results of past decades of education have created an independent spirit and advice is neither sought nor welcomed in the large stores. The open-door with opportunity for handling fabrics and even for this privilege to be made into a form of recreation has also provided the means for the cultivation of judgment. The great variety of materials and colours must have had its effect in this direction. The retailer—a good practical psychologist—has not been slow to encourage and sustain an emotional interest. Talcum powder on a film-star, as mentioned by Mr. Whittaker, may not appeal to a matter-of-fact man, but the dresser of attractions is wide awake for indirect sales and might even use a shade card of 104 tones of pink if this seemed likely to catch the interest of a large and important dyeing community.

The modern methods have one decided disadvantage. The customer has only a very superficial knowledge of the probabilities of wear and this is obtained mainly by handling. If the experienced buyer is not consulted there is a danger of complaints. Retailers have grasped this weakness and assume that the customer is always right. Goods will be exchanged or the money refunded in almost all cases, whoever is at fault. This bridges a chasm in judgment and allows the preferences by appearance and handle to have more concentrated attention—without any doubt on the unknown points of wear. This is the retailer's guarantee and applies throughout an establishment. It pays well in increased sales and the cost on turnover is " infinitesimal," especially if compared with the cost of advertising.

Moreover, if even from a " ridiculous " selection, or the unsuitability of an article for a purpose, the customer is irritated by questioning and lengthy discussion, there is a possibility of serious damage being done by misrepresentation of the facts to others. With good faith, any adjustment necessary is arranged with the manufacturer or the retailer regards the the differences as an overhead charge. Increased sales mean increased production for the manufacturer ; this encourages a give-and-take settlement which I am assured is usually amicably effected.

Where differences exist it is surely much wiser to submit them to impartial authorities set up, we hope, in the near future by the British Standards Institution and the Textile Institute with the co-operation of the Society of Dyers and Colourists. I would further stress a desire that official recognition should be given to Chambers of Commerce arbitration for specific types of goods ; this recognition might make the form of that accorded to Technical Colleges, whose internal examinations reach a required standard. In this way commercial judgments would be used to advantage, especially if they are made more impartial by psychological methods.

Conclusion

It will be recognised that appearance and handle, in their appeal to the senses, must play an important part in all textile matters. Many factors, including that of wear, are estimated by the sense of touch. Physical and chemical tests, which take an almost exclusive place in some industries for the measurement of suitability and utility, take a definitely second place in textiles. From a scientific point of view, relatively nothing is known about the mechanism of the sensitivity of touch when, as in trade, its many qualities operate as a whole. Little is known of the relationship of the hand and eye in judgment. There is a sharp division between main groups of psychologists as to the importance of dealing with mental processes separately or as a whole. In industry, sectionalism stresses the details of parts which technology has measured, tabulated and published. But, there remains an empirical practice which, in every department, is proved by experiment to be more accurate and rapid than is commonly supposed when the parts are treated as a whole. This we term " judgment."

The natural judgments of children, the empirical judgments of adults and the intensive judgments by experience need further exploration. Recognition must be made of the value of impartial physical and chemical tests. All are essential in an efficient organization and none can afford to despise the other ; mutual co-operation is fundamental to success.

THE WEARABILITY OF FABRICS

A COMMENT FROM THE POINT OF VIEW OF THE LAUNDERER

By F. Courtney Harwood, B.Sc., F.I.C., M.I.Chem.E.
(British Launderers Research Association).

Mr. Whittaker has sub-divided wearability into several factors and I propose to confine my remarks to that factor with which I am most directly concerned, namely resistance to washing. Mr. Whittaker has referred to the slogan " the customer is always right," but there is another which is seldom quoted, but which is undoubtedly popular in some circles, namely, " the laundry is always wrong." I mention this because I wish to point out that the laundry quite often receives more than its fair share of blame in connection with the failure of textiles. Many faults and damages only become apparent on laundering and frequently it is not possible to allocate the responsibility for these. The result is that since the blame cannot be equitably placed on any individual or firm it is promptly laid off on to the launderer and he, being quite defenceless in such cases, has to choose between losing a customer and paying up ; usually he adopts the latter course.

Let us consider the descriptions which are applied to some classes of textiles. Mr. Whittaker has done much to point out the misuse of the word " fadeless " and I should like briefly to call the attention of the Conference to another term " unshrinkable." It is a regrettable fact that this term is applied indiscriminately to all kinds of woollen underwear, quite apart from any consideration of whether the fabric has received an adequate unshrinkable finish and apart from any consideration of fabric structure.

I am not sure whether all manufacturers use the word as an implied guarantee (although some certainly do so,) or whether its misuse is now so extensive that it is considered a good selling point. Of course, in the textile world it is realised that at best " unshrinkable " is a relative term and possibly some of the general public appreciate this also. A large proportion however, certainly does not.

This mis-description of woollen underwear is extremely unsatisfactory for it is only reasonable to think that garments so marked should be capable of being washed without undue shrinkage, by a process which has proved to be suitable for woollens which have been adequately chlorinated. This, however, is by no means so. From the point of view of shrinkage, woollens which have received adequate chlorination can be quite satisfactorily washed in a rotary machine, provided suitable precautions are taken, particularly with reference to the amount of mechanical motion received. When many so-called unshrinkable woollens are washed by such a process the result varies from the merely unsatisfactory to the extremely bad. To illustrate this I would refer you to the small exhibit provided by the B.L.R.A. for this Conference. We have in the past carried out test washes of many of the leading makes of underwear, but for the purpose of this exhibit a number of vests was purchased at random and washed together ten times. All the garments were marked " unshrinkable " with a permanent or temporary mark, or were labelled in such a manner that unshrinkability was implied. The garments really require no commenting on for they obviously vary from satisfactory to hopeless. If we consider the size changes

on a basis of superficial area obtained from the length and breadth measurements then we find there has been little change with the man's satisfactory vest—21 per cent. area shrinkage with the other man's vest, whilst with the ladies' vests the figures are 37 and 59 per cent. ! The more open knit of the ladies' garments has, of course, a definite bearing on the extent of the shrinkage.

I think these figures indicate the absurdity of the present widespread marking of woollens as unshrinkable. You may say—but these garments do give satisfactory service if they are washed according to the instructions which are supplied by some manufacturers. Admittedly, even the garments previously referred to will stand up fairly satisfactorily to a gentle hand-washing process, but what is the use of basing a statement of unshrinkability on a washing process which is frequently incapable of effecting adequate cleansing ? It is evident therefore, that the term "unshrinkable" falls into much the same category as "fadeless" and as a consequence gives rise, in the minds of the purchasing public, to an erroneous impression of the wearability of garments which are so marked.

THE WEARABILITY OF FABRICS
A COMMENT FROM THE POINT OF VIEW OF THE LINEN DYER

By H. B. Bradley, B.Sc.
(Linen Industry Research Association)

It is a well-known fact that the flax fibre has inherent properties which have given linen fabrics a reputation for genuine value and beauty, and this should be kept in mind by all who endeavour to maintain the position of the linen section of the textile trade. In the last few years scientific research organised by the manufacturers of dyestuffs, auxiliary products, and textile machinery has contributed much valuable knowledge which linen manufacturers and designers should exploit to their fullest advantage in maintaining and furthering the characteristic attractiveness which linen possesses in the eyes of the general public. The inherent fineness of the raw material, flax, the foundation of linen materials, is worthy of every effort on the part of the manufacturer, designer, dyer and finisher, to place before the public a material which has genuine attractiveness combined with real wearing qualities and serviceability, and is in every way worth its price.

There is now an extensive range of dyestuffs of good all-round fastness available, and it is regrettable that acute price-cutting, a consequence of present-day sales competition, should prevent the fullest use of these dyestuffs being made, as they could contribute greatly to the serviceability of linen dress goods. Inferior dyeing, resulting in fading, and poor fastness to rubbing, washing, laundering, perspiration, etc., detract from the aesthetic satisfaction of any garment, and will affect the reputation of linen goods more than in the case of other materials.

Similarly, with regard to attractive and permanent finishing effects, the various new methods and treatments are doubtless capable of enhancing the selling value and quality of linen, and although at the present time our knowledge of this branch of textile technique is not as comprehensive as in the case of dyeing, the future will probably reveal even more remarkable advances than the last few years have done for the dyer. Organised research has already obtained a footing in this sphere, and further efforts, if strongly encouraged, will bring great benefits to the manufacturers of dress materials.

One of the greatest difficulties in linen dyeing is the problem of obtaining fully penetrated dyeings, particularly when using the faster vat dyestuffs. In the case of the insoluble azoic dyestuffs produced on the fibre, penetration is not such a serious difficulty. Soluble derivatives of the leuco-compounds of vat dyestuffs give good penetration but can only be used at present in the production of pale shades on account of their very high cost of manufacture.

Vat dyeing has lately been facilitated in this respect by the introduction of methods and machinery for forcing the dye while in the unreduced state through the fabric by mechanical pressure, followed by reduction and fixation of the dye as a distinct stage of the dyeing process. This novel application of vat dyes has not the simplicity of direct application of the leuco-compounds in the dye-jig, but it is probably the most promising approach to solving the penetration problem. The Linen Industry Research Association is devoting attention to this difficulty in linen dyeing.

THE WEARABILITY OF FABRICS

FASTNESS TO LIGHT AND LAUNDERING

By P. W. Cunliffe.

Of the factors which control the useful life of a textile and which have been conveniently detailed by Mr. C. M. Whittaker, I would refer to those of light and washing.

It is probably true that many of the public expect the impossible from a fastness point of view, but nevertheless they have cause to be dissatisfied with a rate of fading which was shown a few years ago by a printed cotton dress which became entirely bleached after a morning by the sea. A short test would have shown the folly of marketing such wear, which could not have done other than produce a dissatisfied customer. It has been said that the degree of fastness which can be expected of a textile is that of its useful life; this may be a vague period, but it does at least give some sort of basis on which to work. It is obvious that periods of time ranging from a few days to a few years are involved and that parallel with this is a similar wide range of fastness requirements.

In any scheme of testing, it is thus necessary to allow for a range of fastness, rather than to make an arbitrary dividing line between fast and fugitive. The use of the word " fadeless " does, of course, imply such an arbitrary line of demarkation, and from this point of view alone is most unfortunate. Much has been said against this and similar terms from other aspects, but their use is still favoured by the retail trade, as a selling point. The range of fastness to light of present-day dyes is very considerable, and while some may be regarded as out-of-date, there remains a use for many of relatively poor fastness, owing to their possessing other valuable properties.

Tests for the fastness of dyes to light have been in use for a long time, but a standard method has not been available until the last few years. The story of the pioneering efforts of the German Echtheitskommission is probably well known to all present, while the work of the Society of Dyers and Colourists in this country has recently been to the fore.

The ideal way of approaching this problem would be to expose the material to be tested for a given time to a source of light of sunlight quality and to measure the colour, before and after fading, on a colorimeter, expressing the change in colour as a certain number of least perceptible visual steps.

The colour measurement portion of the method presents the greatest obstacle, since the data required for converting instrumental data into visual steps are inadequate. Exposure to a light source of the type mentioned is practicable, however, and is carried out by the British Cotton Industry Research Association. Unfortunately, the cost of equipment and maintenance is beyond many laboratories. The use of the ordinary carbon arc, which has a continuous spectrum but the distribution of energy in which is not the same as in sunlight, has been widely used and is well known in the form of the Fugitometer and Fadeometer.

Many of the difficulties of testing are obviated if there is available a range of coloured surfaces of graded fastness which can serve as standards, against which test samples may be compared. These behave virtually as light

integrators, thereby allowing the use of a source of light of variable quality and intensity. This means that a continuous exposure can be made to sunlight on the one hand, and that any fluctuations in a fading lamp are automatically compensated.

Considerable work has been carried out in this and in other countries on the production of such a range, and it may be claimed that there is now available a satisfactory working set of standards of graduated fastness. These standards of dyeings on wool cloth but serve to test the fastness of all coloured textiles.

The several national committees on fastness, particularly of America, England and Germany, have recently come together in an endeavour to agree on a common set of standards. Considerable advance has been made and it is confidently expected that at the conclusion of a series of tests being made this summer, this desirable object will be achieved. It may be stated that the latest standards of the German committee differ but little in fastness in each grade from those of the Society of Dyers and Colourists.

Here then will shortly be available a range of eight standards accepted internationally. There appears to be an excellent opportunity of making the fullest use of a system so widely agreed upon. Could not the public be led to appreciate the significance of a scale of fastness ? Perhaps that is expecting too much. Even if the use of fastness numbers extended only as far as the retailer, considerable troubles between seller and purchaser might be avoided.

The problem of testing the fastness to light is not entirely solved, however, by means of standards. In the first place, the standards so far proposed are all in medium to dark shades. A difficulty at once arises when the fading of a pale shade is to be compared with that of the deeper standards. Moreover, the standards of the Society of Dyers and Colourists comprise a range of blue and a range of red dyeings only, while those of the German committee are in blue only. In comparing a yellow, for example, with such hues, a personal factor enters to an appreciable extent.

The Fastness Committees of the two countries mentioned have not, so far as the speaker is aware, made any investigations on these matters. Some attention has been given to the problem of interpretation, however, by the Fastness Committee of the Technical Section of the Papermakers' Association during the last two years. They faded forty-five coloured papers and invited thirty-six people in various occupations to classify them in terms of an exposed range of standards on wool, no instructions being given to the observers. The lack of agreement between the observers was surprising only 29 per cent. of the samples being placed in one or at most in two groups. A number of simple instructions was then drawn up and the observers asked to repeat their classifications. The agreement was slightly better. A simple viewing box was then constructed and the observations again repeated. This raised the number of samples classified in one or two groups to 42 per cent., or when the best two of three judgments were taken, to 76 per cent. It is probable that the agreement would be better when all the samples comprise textile fabrics rather than some of paper, but nevertheless the results obtained indicate the presence of an important personal factor which should receive further investigation.

The washability of textiles involves either the fastness of the colour or the tendency to shrink, or both. The investigations of each of the three national committees previously mentioned have resulted in a series of tests for each country. Considerable differences between the three series are found. It may be noted that the German tests are carried out by the plaiting method and in beakers, while the American and British tests require a Launderometer or experimental wash-wheel. This naturally limits the use of the tests to those possessing such a device, that is in general, to a few larger firms and to the Testing Houses and Research Associations. There are, of course, advantages in leaving such testing to a central authority with its impartial outlook and wide experience of testing methods.

The tests put forward by the Society of Dyers and Colourists for fastness to washing are concerned with cotton only. The need for a standard test for wool materials has been recognised for some time by the Wool Industries Research Association, who have now begun investigations on this subject. A Technical Panel has been formed to represent all interests and this valuable co-operation should result in a more general acceptance of the standard tests when finally worked out.

The second factor involved in washing textiles is shrinkage. Attention has been paid to the determination of this quantity with cotton goods, but it is rather surprising to find that no method of test has been published for fabrics made of wool. The Wool Industries Research Association has appointed a Technical Panel and has carried out an investigation during the last year in close collaboration with the British Launderers' Research Association and other bodies. The Panel distinguishes between the shrinkage due to the release of strains introduced during manufacture, and the shrinkage due to felting caused by the washing process.

Series of washes on four types of fabric have been made by members of the Panel in commercial machines, while at Torridon a modified wash wheel designed to take tests pieces up to 50 grams in weight has been installed. This machine, which is fitted with a reversing mechanism, can be modified to give any desired degree of severity, and thus reproduce the conditions from a very mild wash to a severe power machine wash. The wash wheel gives results which are closely reproducible, thereby possessing an advantage over commercial machines. Moreover, it has the additional advantage that the same device may be used for testing the fastness to washing of coloured goods.

It is anticipated that the procedure which has been adopted for the determination of shrinkage will shortly be published as a provisional standard.

THE SERVICEABILITY OF FABRICS IN REGARD TO WEAR

By T. C. Petrie

Dr. Peirce states that imitative tests are a delusion and a snare " but what is wanted are tests to measure characters, defined by behaviour under the simplest conditions." I feel sure that this is correct.

Mr. Whittaker sub-divides the matter under the headings:—

Structure,
Resistance to light,
Resistance to washing,
Resistance to friction, perspiration, etc.,
Resistance to sea water.

I would certainly add to the perspiration factor, the different kinds of perspiration, for long observation has convinced me, that different types of human beings cause varying degrees of felting to their woollen underwear. Fair-skinned, blue-eyed people, never seem to shrink their woollens, whilst dark, swarthy people do—the wool in this case is not only strongly alkaline, but also frequently contains a high fatty content. It is obvious that both alkalinity and acidity react unfavourably with certain dyes. Then there is the problem of the buyer, mentioned by Mr. Whittaker, but there is also the important problem of the designer. Does he always bestow the necessary care in considering for what purpose the fabric is to be used, and the conditions arising in use ? At times it becomes painfully evident that a straining after-effect gives rise to much trouble in wear, and in laundering. For example in high quality silk pyjama fabrics, with long floats of silk yarn of low twist, the silk yarn simply rubs out in wear, and if washed, the yarn loses its continuity. Shirting fabrics of high quality are frequently encountered where the fabric is quite suitable for its purpose, but the collar to match the shirt is not, owing to the fact (1) that the collar has a fold, and (2) the warp yarns are running the length of the collar. In the first case, the weft running over the edge of the fold is subjected to the strains and stresses set up by the thickness of the fold. In the second place it receives the rub not only of the neck itself, but also that of the inside of the coat collar. If the coat fabric is of a harsh type it adds to the abrasive action of the neck. Some necks are wonderfully bristly, which can readily be observed by examination of collars at the front, as well as along the neckband.

Again, does the designer ever consider the effect of wetting and the inevitable contraction which takes place ? Take for example, a recent type of sheet, where a thick cord takes the place of hemstitching. The latter was bad enough, but the cord idea is worse. Such a cord, or rib, on wetting, contracts, stresses and strains are set up, the warps are distorted, and very often so are the wefts. Such an article should be calendered, but the presence of a cord, causes much trouble, first of all, to straighten the piece, then having done so, by exerting a good deal of strain without real avail, the piece is calendered with the result that a dried, wrinkled, trenchlike line runs parallel to the cord, or rib, and the selvedges are pulled out of alignment. Such an article cannot give a satisfactory life, nor can it meet with the approval of either the owner of the sheet, or the launderer thereof. Ribbed fabrics, such as shirtings, always split parallel to the ribs, the wefts reach their breaking strain due to the stresses set up by the contraction of the relatively heavy yarn producing the rib. The same trouble arises with monograms

and motifs, due to the high twist yarns used for embroidering lighter weight fabrics, disruption taking place at the letter terminals, and such like.

Another fruitful source of trouble arises in the hands of those who make loose covers. It would appear that the aim is to get these covers to fit furniture as a glove fits the hand. As insufficient allowance is made for the loss of imparted stretch, a great deal of trouble arises, and generally the laundry is blamed. But it must be borne in mind, that there is no known washing process which will cause shrinkage of the cotton or linen fibres. In many cases, the presence of a thick binding cord, ensures that no stretching is possible during the finishing process, and of course, the cord contracts to a different extent from that of the fabric. Would it not be possible to indicate to the maker-up what allowance should be made ?

Very often too, the colours rub off in the dry state, and this is not observed whilst the covers are in use, but the effect is intensified with even the most carefully controlled washing process, the colloidal property of the soap greatly increasing the colour loss. A selection of the bottled extracts so obtained, is very illuminating. Cold water soaking will often remove colour, the friction factor not entering into the question at all.

A great service can be done for all concerned, if only the manufacturers and the laundry industry, put their minds to closer co-operation. It is true that within recent years an increasing number of large and well-known firms have done, and are doing this, by working with the Fabrics Investigation Committee of the Institution of British Launderers, who are only too pleased to consider the problems submitted, and to advise suitable processes, before the goods are placed on the market.

It is obvious that the more we know of each others' difficulties, the sooner ways and means can be devised for overcoming these, for it is a fact that our fortunes are inextricably interwoven, and so we stand or fall, according to the judgment of the consumer.

SERVICEABILITY OF FABRICS

By H. C. Barnes.

Dr. Peirce gives us a practical and philosophical, as well as a scientific, guide to the principles of testing, and it is difficult to do other than support one or other of the points. Other scientific workers and technologists or testers do, occasionally, give the impression that the function of the industries themselves is the advancement of science or of technology respectively. In such cases the tail seems to be wagging the dog ; the danger is only aggravated if it is a most intelligent tail and a rather stupid dog.

In the minds of the textile producers the trade might rather be considered as a means of finding employment and income by appealing to human satisfactions or vanities. It succeeds by making the consumers " textiles conscious" to a greater degree. A new frock is a new opportunity of self-expression, and its question of durability, or even appearance, may be secondary. Some purchasers might like to have a new one for every occasion if they could afford to buy it. The psychological, aesthetic, or economic aspects may thus take precedence over the technical or physical properties. The public is using paper serviettes or table covers and paper towels and even textile articles once only, and most of these would not pass the most modest textile standard test or specification. At one time cotton was legally proscribed, being judged as a base substitute for wool, and one only need remember what rayon was a few years ago before it became the cheap and profitable luxury article of to-day and perhaps the staple of to-morrow.

The brief examples might serve to show that in the evitable move towards standardisation the test methods or standards of goods should be permissory or exclusive rather than compulsory or inclusive and that they should never be considered to be final. The trade itself would seem to be right in resisting any attempts by distributors, or even by producers of better quality lines, to restrict its field of appeal or its economic scope. In plainer words, producers should not be stopped from producing so-called rubbishy or " unsound " fabrics or cheap textiles. Better quality or " sound " fabrics can be certified or trade marked but would it not be bad policy to take active steps to suppress the others or in fact force specifications on everything ?

ABRASIVES FOR WEAR-TESTING

By J. H. Lester, M.Sc., F.I.C., F.T.I.

When two portions of a uniform fabric are rubbed together, it may be said that the abrasive is definitely standardised, but the value of such "cloth-on-cloth" tests as an indication of the life of a fabric in actual use has yet to be explored or determined. Such tests may easily be made by the "Herzog-Geiger" or the "Ring-Wear" method. It would seem obvious that this method of testing very closely similates the conditions of wear at the armpit of a garment and where the sleeve is rubbed against the body, but for all that it cannot yet be said that the relation between the test and the conditions of use has yet been found to be significant or satisfactory. Since the abrasive surface itself is changed, however slight a change is made in the fabric under test, it is in practice very difficult and perhaps impossible to interpret the results of these cloth-on-cloth tests, or at any rate to attach any significance to them under conditions other than those where two surfaces of the same fabric are rubbed together in an arbitrary test.

We find a tendency to-day to discard the use of carborundum or other abrasives which have, or are supposed to have, a severe cutting action upon fibres, though it must be admitted that if a number of different kinds of fabric are tested with carborundum and also with a softer abrasive, they are often found to range themselves in the same order of merit.

That the nature of the abrasive not only affects the rapidity but the essential character of the results is shown in a very marked degree when fabrics of cotton and of spun viscose are compared.

Abrasive.	Cotton.	Viscose.
Card Clothing	263	635
Ring-wool	2880	830

The reversed superiority of the two fabrics according to the abrasive employed, clearly indicates that essentially different physical properties are measured by the different abrasives. Some light appears to be thrown upon these different properties when we examine the tested and worn-out fabrics, the cotton showing a hairy or flannelette-like surface, while the viscose fabric is relatively sheer. Some progress is certainly being made towards the better understanding of wear tests by providing a number of testing machines, each of which attempts to measure only one of the several factors which cause fabrics to be worn out, but it is, of course, almost impossible to eliminate secondary disturbing factors from any one test. The Amsler type of machine attempts to eliminate surface friction as far as possible and to produce the maximum of friction between fibres throughout the fabric, by the use of smooth steel rods which flex the whole structure; but surface friction still plays some part. Experience with the use of card-clothing, whereby a brush of steel wires is "trailed" over the surface of the fabric, shows that although the effect is largely one of surface abrasion, it results in much teasing out of the fibres, provided of course that they are not too hard or brittle to be withdrawn from the fabric.

This experience clearly suggests that one factor in the resistance of a fabric to wear is the resistance of the fibres to forcible withdrawal from the fabric and at the same time their resistance to breakage during withdrawal.

The tendency of some fabrics to develop a flannelette-like surface during testing and during wear, is certainly one which needs investigation, for while it may quite spoil the appearance of the fabric, the "raised" surface

undoubtedly affords some protection against further wear. And closely allied to this raising of surface hairs is a defect to which some wool-containing fabrics are subject—in that they become scattered with tufts or " neps " of fibre more or less rigidly attached to the surface. The tendency to produce such neps might easily escape notice in most existing wear-test machines, but it should not be difficult to produce when large surfaces of fabric are rubbed together in suitable directions.

It is this tendency to form masses of tangled fibres which has prevented the wider use of what has been called the rolling-crease method of testing, making it indeed only applicable to fabrics made from relatively brittle fibres which, when broken, can easily be removed by blowing or brushing away.

While the subject of fabric-wear testing still presents a rather tangled mass of information, it by no means follows that the only progress to be made must be along the line of devising methods which attempt to separate one physical character from all others. Even should we arrive at such methods we shall have an equally difficult task before us—to determine the relative importance of those physical characters to each other in respect of different fabrics used for different purposes. Nor is the selection of a suitable abrasive more than one of a number of factors which must receive our attention. Whatever the abrasive, we cannot overlook the presence of the broken fibres we always produce, in themselves a very disturbing abrasive. But it would be out of place here to deal with many other disturbing factors, such as the presence of small amounts of lubricating substance in the fabric ; the moisture content and the effect of the heat generated by friction upon that content ; standardisation of the tension of specimens under test and of the load to be applied, etc.

The Significance of Results obtainable by the ring-wear method of testing, when wool fabric is used as abrasive, may be outside the scope of this paper, but a short note on the subject will be found useful to those who may use the machine. The casual observer will be tempted to regard a sample which is worn out after 400 revolutions as being " twice as good " as one worn out at 200. Perhaps it will be in actual use as a garment, but in view of the fact that fabrics in common use show figures varying all the way from about 100 to 10,000, the significance of the difference between 400 and 200 may easily be exaggerated. In similar manner, the significance of such a difference as that between 400 and 200, when obtained from two specimens of " the same fabric " *may* not be serious.

THE FRAYING OF FABRICS

Some fabrics are more or less unsuitable for use as garments due to fraying at the cut edges, and consequent gaping at the stitches or complete rupture at the seams.

An early attempt was made to measure the tendency of a fabric to fray by cutting a clean edge along the warp or weft and measuring the tension required to withdraw successive threads.

A visual method of comparison was then adopted, the fraying being accelerated by washing under standardised conditions in the " Whirldry " washing machine. This gives considerable movement to the fabric by means of frequently reversed rotation. The samples were cut in triangular shape, thereby showing the fraying effect in warp, weft and diagonal directions. The sheet herewith illustrates most clearly the greatly varying degree of fraying to which different fabrics are likely to be subjected in use as garments, and particularly as the result of laundering.

In order to obtain roughly quantitative results the following method is proposed.

Sample strips measuring 12 ins. × 2 ins. are cut in the diagonal, warp, and weft directions. The strips are marked by lines across the width, one 2 ins. from one end, and the other 4 ins. from the other end, weighed, and given a severe laundering treatment under standardised conditions in the "Whirldry" washing machine. The strips are then dried and conditioned, 2 ins. being cut to waste from one end, and 4 ins. cut from the other end to be preserved for visual examination. The remainder is a strip 6 ins. × 2 ins. The fringe at both sides is cut off with scissors as nearly as possible to the line which separates the frayed and unfrayed areas. The unfrayed area is weighed (a). The original weight of the 6-in. strips is assumed to be half that of the original strip (x).

$$\text{Therefore percentage fraying} = \frac{\frac{x}{2} - a}{\frac{x}{2}} \times 100$$

The test is, of course, quite an arbitrary one, but it conforms reasonably well to the conditions of use of fabrics and serves as a useful guide to the suitability of fabrics for use as garments.

The tendency of some fabrics to fray is closely connected with what we know as "slipping", but we are not sure that fraying tests are always due to the same inherent causes as slipping.

It has been common practice to join the ends of two strips of fabric together by a seam (or to make a seam across a strip of fabric so as to make a pleat), and to measure the width of the stripped area when the whole strip is subjected to a fixed tensile load. (Alternatively the stripped area has been measured at certain degrees of extension of the strip, generally 4 per cent. or 8 per cent. of the original length.) This test suffers from the defect that it takes no account of the elasticity and/or elongation of the fabric under strain, and it is certainly true that a very elastic fabric is less liable to slippage in actual use as a garment than one which is much less extensible under load. In view of this, a slipping test has been devised which appears to possess the advantage of being influenced to some extent by extensibility. It may make the following statement clearer if we say that when different fabrics are gripped on both sides of, and quite close to, the seam, they may require the same load to cause slippage, but that if we grip the fabrics at some distance from the seam, more elastic or extensible fabrics will withstand a much greater load before slippage takes place.

A strip of cloth 6½ ins. wide and 12 ins. long is seamed across in the usual way, one end being held in the "weighing grip" of a Goodbrand testing machine, the seam across the strip being placed at 1 in. from, and parallel to the weighing grip. The other end of the strip is attached to the "pulling grip" of the machine so that the free distance between the two grips is 12 ins. The attachment of the strip to the pulling grip is made by inserting a piece of thick rubber covered fabric above the fabric at the middle of the grip, and consequently the pulling grip of the machine only exerts its action upon a 1-in. width of the fabric. The maximum slippage at the seam is recorded.

It is clear that if the fabric be inextensible, the load applied at the pulling grip will only affect a somewhat limited length at the middle of the seam, but that with an extensible fabric the load will be distributed over a much greater width. With the same amount of loading the more extensible fabric will show less slippage than the inextensible.

THE SERVICEABILITY OF FABRICS IN REGARD TO WEAR

By W. H. Gibson, D.Sc.
(Director, Linen Industry Research Association)

The introductory paper contributed by Dr. Peirce on this subject is of much interest and wide range. When I began to read it I felt quite hopeful of finding some aspects of the subject which had not been covered, because Dr. Peirce began with definitions, and definitions have a way of limiting one's scope. However, Dr. Peirce has not been unduly suppressed or compressed by his definitions and I have not found my task so easy. While it may be an excellent thing to define your terms, I am not sure that a textile technologist or anybody else is under any obligation to accept the rendering of the Oxford Dictionary.

In a living language meaning is constantly changing and the lexicographer can only toil after it in vain. Any visit to the "talkies" will convince you of this. In developing my argument I am more concerned to consider what is most important in the title "The Serviceability of Fabrics in regard to Wear," taken as a whole.

It seems to me that the only interpretations of this title that matter very much are those which relegate the idea of impairment of quality by friction to the background.

I am afraid I take a different view of the tests which Dr. Peirce is pleased to call "imitation wear tests." Surely the conditions under which such tests are done are chosen in the endeavour to limit the variable factors so far as possible and so to obtain reproducible and comparable results. We are admittedly often a long way from succeeding in this, but I would not like to try to "make the punishment fit the crime" in each individual investigation into fabric wear.

Wear of a fabric is such an individual matter that one person's use is another's abuse. If anyone looked at his boots he would admit that the incidence and intensity of wear on them is peculiar to himself.

Passing from the boots, we come to the hole in the heel of the stocking, known to the London child as the "tater." The wear which brings this about seems to me to be practically infinitely variable. It depends on the wearer, the wearer's activities, the make of the boot or shoe, and the fabric of the stocking. The user or the unfortunate parent of the user is alone able to decide whether the stocking is serviceable in wear. The individual thus finds through bitter experience that the best thing to do is to buy so many pairs of blank brand stockings per annum at such and such a price according to his means, Manufacturers of stockings then find that their goods are serviceable, that is, they are in strong demand, particularly in the bargain basement. The same thing applies to other garments. Having a saleable fabric, it seems to me that the manufacturer has quite a fair chance of making improvements on it by the use of those comparative and reproducible "imitation wear tests" which Dr. Peirce dislikes so much. It seems to me that the use of such tests is to show whether the quality of the fabric manufactured is being maintained or, if research is in progress, improved. They are controls which allow the manufacturer to offer his goods to the public with some hope that they will serve without giving rise to undue complaints. There is a way of approach to this question of the serviceability of fabrics in regard to wear which seems to me to be simpler because more human.

Through the experience of generations, we have come to use fabrics made of the textile fibres, silk, wool, flax, cotton, jute and a few more, for purposes for which they have been found suitable. These fabrics are suitable for their particular purposes because of the natural or acquired properties of the fibres from which they are made and because of the structure into which they have been arranged.

The customer is always right, and should know whether he or she wants silk, wool, flax, cotton or jute fabric for any particular purpose. This fabric should be available and it should be possible for the retailer to assure the customer that the fabric is genuine. Tests of identification of the textile fibres in natural and modified condition are thus of paramount importance.

I am afraid that old-fashioned people were far shrewder buyers than those of the present day who are too content to look at the price ticket. The public needs education in buying. I can illustrate this point by an old Scottish story about a Highlander who was wanting a new plaid. He went to the weaver and the following conversation ensued :—

Buyer :	Oo ?	Wool ?
Seller :	Ay oo.	Yes, wool.
Buyer :	Aa oo ?	All wool ?
Seller :	Ay aa oo.	Yes, all wool.
Buyer :	Aa ae oo ?	All one wool ?
Seller :	Ay aa ae oo.	Yes, all one wool.

There was no question here of tests for serviceability but a firm conviction that if the fibre itself was genuine, serviceability would follow.

In the same way in the linen industry to-day we endeavour to give users, who want linen, fabrics made of pure flax, and to protect them against the substitute-monger. Control by fibre identification tests is the best way of doing this.

Since most fabrics are submitted to finishing processes before they are worn, the question of modification of the natural fibre during these processes is an important matter. The chemical tests which give an indication of the condition of the fibre are invaluable in safeguarding the interests of the user in this respect and are in wide use. The levelness of the yarn from which the fabric is made may have a bearing on the serviceability of a fabric for some particular purpose but this is a point which is usually in the mind of the weaver. We are then left with the effect of structure of the fabric on its serviceability in wear. We all know perfectly well that a straightforward plain weave is more durable than any other because the binding effect of the weave exerts its maximum effect. We also know that the durability of the cloth increases with the increase in the number of ends and picks per inch up to a maximum. Apart from this, the heavier a cloth is, the more durable it will be.

However, considerations such as these have very little to do with serviceability which is really determined by fitness for purpose. It would be absurd to limit the range of textile fabrics to plain, close, and heavy weaves, and, in fact, the demands made on the manufacturer by the good taste and individuality of his customers could not be met.

There is and will always be a large proportion of the public which takes a pride in its clothes as a means of expressing personality and its moods. No woman will scrub the kitchen floor in a ball gown, and she will not be

restricted in her choice by absurd considerations of mechanical wear. We should bear in mind that fabrics in use are subjected to two kinds of wear, personal wear, which is the most important matter, and the wear involved in cleansing the garment, which is dependent upon the effects of personal wear and upon the methods of cleansing adopted. There is a danger that textile manufacturers may be led to attach an exaggerated importance to the " launderability " of fabrics. Launderability appears to be the ability of a fabric to stand a standardised mechanical washing process. Unfortunately a washing machine cannot discriminate between a robust and a delicate fabric in the way that the hand of the laundress can, and judging from the Press, there is a movement towards hand washing of delicate garments.

If we are gradually becoming a nation of " daily dippers " it may be that the flimsiest of garments will give perfect satisfaction to a large class of buyers and wearers, although they would not be approved by launderers.

Finally, there is no such thing as uniformity in personal wear. The individual judges the serviceability of a garment by the number of times it can be worn and still look smart and not dowdy or old-fashioned. Some people have a greater flair for wearing clothes than others. The suitability of the style and the excellence of the cut of a garment are bound to have more effect on the serviceability in wear of the garment than anything else. In extreme cases, which do occur, the garment is unwearable from the first. It seems to me that there is a great deal to be said for the encouragement of the small tailors, dressmakers and milliners who can give individual attention to style and cut on behalf of their customers. Reach-me-downs will never give quite the same satisfaction, even if worn by all the most celebrated or notorious people.

To sum up, the view is expressed that serviceability in wear is to be secured by ensuring that the wearer gets what is wanted. The fibre composition can be guaranteed by fibre identification tests. Proper treatment in finishing can be controlled by chemical tests. The structure of a fabric can be analysed and defined.

Mechanical tests are useful for purposes of comparison, but mechanical wear is not the chief consideration in determining serviceability for wear.

The chief consideration is fitness for purpose, and this means that a garment must retain its attractiveness for the required period of time.

THE WEAR TESTING OF KNITTED FABRICS

By Professor W. DAVIS, M.A.

(Department of Textiles, University College, Nottingham)

It is of considerable importance that some system should be employed to give an indication of the service which a knitted fabric is likely to give in wear. The problem has a number of facets, but it is considered that the resistance of the fabric to rubbing or abrasion is one of the most important.

The apparatus devised for this work was fully described in the issue of the *Journal of the Textile Institute* of April, 1934, T133-T140, and is included amongst the working exhibits of the Conference. To recount the main features, the fabric to be tested is placed over the upper surface of a leather ball, inflated to a pressure of 2·25 lb. per sq.inch. Between the ball and the fabric is placed a piece of chamois leather which keeps the test piece in position. The fabric is subjected to the side-to-side rubbing action of an arm, to the lower end of which is fixed a roller and round this is closely wrapped a standard piece of woollen double-cloth overcoating fabric. The abrading arm is set to give about 108 beats per minute. The fabric is rubbed until a hole appears and the number, registered on a counter, is taken as the measure of the test. The object is to rub fabric on fabric and to have a yielding action on a curved surface which is considered to represent the wear of an under-garment at knees, elbows and seats. A gauge is employed to ensure that the ball rises to a standard height and the variation in pressure is indicated by a column of mercury ; when the temperature rises, pressure inside the ball increases and air is let off, whilst leakage of air is remedied by pumping in more to maintain the mercury at the correct level. The fabric is stretched over a tambour frame, and by hanging the same weights all round the circle, the tautness remains the same for all tests. The roller with the abrading fabric is turned round a short distance after each trial so that a fresh piece of fabric is available at the commencement of every test made.

If pressures below 1·75 lb. per square inch are used the time taken to complete abrasion is very protracted ; on the other hand, if the ball is inflated beyond 2·5 lb. pressure, the yielding property is lost and one might as well beat against a rigid hard substance. On this basis the range of results of rubbing tests on normal types of knitted fabrics made from cotton or wool lies between 12,000 rubs representing a test of nearly two hours duration and 4,000 abrasions, the latter value being considered to indicate a very poor fabric. These observations do not apply to continuous filament rayon, fabrics made from this develop a very glassy surface after a short period of treatment and some varieties have been rubbed without a fracture for 40-60 hours. This can scarcely be taken as the measure of wear in such fabrics as there are obviously other important factors to be considered.

The method proves useful in comparing the performance of different types of yarns on the same gauge and style of knitting machine. To quote one example, a cotton interlock fabric made from yarn having the normal twist was subjected to a series of tests of which the mean was 10,783 rubs ; another fabric worked under identical conditions on the same machine from cotton yarn without twist gave an average of 9,676, a reduction of just over 10 per cent. This relatively small difference must come as a surprise to most hosiery manufacturers who had rated the benefit of twist at a much

higher figure and who will be disposed to set this relatively small difference against the greatly improved handle of fabrics acquired by twistless yarns.

As regards the unshrinkable process on wool, chlorination often gives appreciably higher tensile strengths when the single yarns or hanks are tested, denoting that the process has a kind of melting action on the structure of the wool fibres. It is known, however, that in actual use, most chlorinated fabrics have a reduced period of wear as compared with untreated. By abrasion this factor can generally be brought out. A sample which gave in the untreated state a mean result of 3,174, had after chlorination a result of 2,462, a reduction of 29 per cent. which may be regarded as having a fair relation to the actual relative performances of the two fabrics in wear.

The method may also be used to show the optimum number of courses per inch which will give the most serviceable fabrics from a knitting machine. Using the same yarn the courses per inch in any machine may be varied from a slack fabric to one which is extremely tight and rigid. A large number of abrasion tests made on such fabrics has demonstrated the greatly reduced service in wear to be expected from fabrics in which the courses per inch have been inserted in excess. Under the beating arm these tight textures receive the full force and quickly wear through ; more normal textures having fewer courses of knitting per inch show much greater resistance under abrasion and such fabrics are much more durable and serviceable.

The knitting industry has to produce its garments shaped and ready to wear and it is often of importance to investigate the performance and durability of various types of seams. These can be made in different stitches, using varying numbers of stitches per inch, and diverse materials and different counts of yarn. Useful abrasion tests can be made on most of those seams, but limitations are imposed on the usual method. Lock-stitch sewing, for example, cannot be reached by the abrasive arm as the threads are drawn into the centre between the two fabrics with a tight tension and abrasion only wears away the fabric. The chain stitch has a similar drawback, except perhaps for masses of chain stitches as in surface embroidery. Most of the other seams, such as the double-chain stitch, the two- and three-thread overlock, the seam-covering stitch, and the flatlock may all be treated by this machine to give interesting and useful results. As the width of the seam is very small it is desirable to adjust the ball so that a ridge is produced and the seam is placed exactly along the line of this ridge, so that it comes more definitely under the action of the abrading roller. Observation of the behaviour of the seams under test give very interesting data regarding the parts which break down first ; in many cases the seaming threads are so firmly stitched that abrasion has little effect on them, whilst the adjoining fabric develops signs of weakness and gives way first. This fact is well known in some types of garments, the fabric is weakened by the seaming threads and the needles penetrating it, and it splits at an early stage of wear. If the system of joining the garment segments is so unsatisfactory, it is of little avail that the ground fabric should be of the most approved construction, as the seam will terminate the usefulness of the garment at an early stage. A caveat must again be entered against the use of this method for rayon fabric, as a separate technique requires to be devised which will give results by a more searching method, within a measurable time.

To quote a practical example, two seams A and B used on a fully-fashioned silk hose were submitted for comparison and report. The mean of a number of tests on A gave 11,709 rubs whilst the mean of tests made on B under identical conditions was 16,451, which to the manufacturer gave useful data regarding the best system of seaming to adopt. Most of those seams have different structures on the face and the back and it is sometimes advisable to make the tests on each side. For example, a five-thread interlock seam will withstand about 70 per cent. more rubs on the reverse side than it does on the face. The results of such trials generally show appreciably higher figures on cotton fabrics than they do on woollen materials, as the bulk of the sewing materials are usually of cotton.

Two- and three-thread overlock seams are best abraded on the reverse side and a satisfactory two-thread seam will withstand over 7,000 abrasions; the three-thread overlock seam, with more thread projecting, will give over 6,000, or definitely fewer than the two-thread join. The face of an ordinary flatlock seam abraded deals mainly with the covering thread which in rayon will withstand 6,000 rubs as compared with 3,800 when wool is used. On the reverse side fracture occurred at 3,500 abrasions.

A series of trials was made on the double lock chain stitch to show the effect of altering the tightness of the seam on the wearing properties. The settings were 10, 14, 18, and 22 stitches per inch respectively, and the seam was made on a standard woollen underwear fabric. The trend to be deduced from a number of tests showed that the lowest number of stitches per inch, 10, gave about 3,300 abrasions, this figure rising in proportion to over 6,000 abrasions for 22 stiches per inch.

Another point of rather academic interest is the temperature produced during the abrading process and the effect of wool on wool, wool on cotton, wool on rayon, and so on, to other permutations with silk and staple fibres. The machine can also be used to compare the amount of fluff or surface fibre produced on fabrics during wear and another use is to examine the behaviour of cotton and wool, mixed fibre and fibre in varying proportions. Many such mixtures show a tendency for one or other of their constituents to be ejected from the centre of the fabric on to the surface.

THE SERVICEABILITY OF FABRICS IN REGARD TO WEAR. TESTING FABRICS TO FORETELL SERVICEABILITY.

By J. LOMAX, F.I.C.

(Yarn and Textile Testing Bureau, University College, Nottingham)

The almost unlimited scope of this subject is very well shown by the contribution of Dr. Peirce who surveys the whole field from a very great height. His conclusion " Imitative tests are a delusion and a snare " is one with which most experienced testers will agree to a great extent, and if our object is to test fabrics to foretell their serviceabilities we may well despair of attaining it. Very fortunately, however, that is not what we are hoping to do.

In actual practice our aims are limited in two ways :—

1. We do not wish to foretell the serviceability of a fabric in any definite terms, such as days of wear, we only wish to compare it with another fabric whose performance is fairly well known, in order to foretell which will give the better performance.
2. In comparing the two fabrics the question of serviceability is usually confined to one destructive agency only, such as washing, the action of which is fairly well known.

If we take as an example a cotton interlock fabric our object will not be to estimate its period of service, but to compare it with one or more similar fabrics in order to find out which will be the most serviceable to one agency, probably friction in wear, whose action can be studied with a view to testing.

It will be appreciated that this narrows the field of enquiry to a great extent, to such an extent in fact that it brings the imitative test within the bounds of possibility.

In connection with imitative tests it should be remembered that tests for fastness to light and washing are imitative, and these are in constant use, and give reliable results. The fastness to light and washing of a new dyestuff cannot be foretold by studying the character of the dyestuff, it can be found only by testing, either by actual practice or by imitative tests. It is probable that the same holds true for the fastness or serviceability of a fabric to friction in wear, that is to say the serviceability cannot be foretold from the character of the fabric but must be found by testing, either by actual practice or by imitative tests. The character of a fabric, count, twist, stitches and courses, etc., must therefore be governed by its performance, which can be discovered only by testing.

There is one important difference between imitative tests for fastness to light and washing and imitative tests for fastness to wearing. The latter are very much more difficult to design, carry out, and correlate with actual practice. This is a difference of fact but not of principle, and it is possible that but for this difficulty testing for fastness to friction in wear would have reached the same high efficiency as the testing for fastness to light and washing, since it is of equal importance.

The difficulty cannot be insuperable in every case. When we consider the manner in which carpets and linoleums are used, lying perfectly rigid and motionless, worn on one side only, and always in the same manner by the friction of shoe leather, with a fairly well defined end point when the backing begins to show through the surface, it does not seem an impossibility to design an imitative test which will place a number of such fabrics in their

correct order of serviceability. Other fabrics, for example cotton shirting, would require completely different tests, which would be much more difficult to design, but not impossible. It does, however, seem certain that any one wear tester must be confined to the particular fabric or class of fabric for which it was designed, and this limits wear testing to a small number of fabrics since it would be impracticable to design enough wear testers to cover all the fabrics in common use.

As an example of the difficulty in forecasting the serviceability of a fabric from its character, the following example may be of interest.

Some time ago a complaint was received on cotton interlock fabric. Two under garments from this fabric were produced, the satisfactory one had been worn and washed for a fairly long time and still had a smooth surface, the unsatisfactory one had been worn for a short time and washed once and the surface was rough, owing to loose cotton fibres fluffing and becoming entangled on the surface. The garments had been made from the same knit of fabric although different yarns had been used. The difference in wear was evidently connected with the two yarns and these were examined for count, twist and staple.

The yarns showed little difference in count, but that from the smooth wearing garment showed shorter staple and slacker twist than the yarn from the rough wearing garment. If an attempt had been made to forecast the wearing properties of the two garments from a consideration of the characters of the yarns used, it would seem reasonable to judge that the yarn with longer staple and tighter twist would wear the smoother. In actual fact the reverse was the case.

Imitative rubbing tests on the two original fabrics showed that both fluffed on the surface with wear. The fluff on the surface of the satisfactory fabric could, however, be brushed away, leaving it smooth, but that on the surface of the unsatisfactory one clung and could not be brushed away. Apparently the lower staple and slacker twist of the first yarn enabled the fluff to remove itself in wear, whilst the longer staple and tighter twist of the second one retained the fluff. Presumably the first fabric would wear smoother and quicker, the second fabric rougher and longer, the former, from the user's point of view, giving the greater serviceability. Such a result could not have been arrived at from a study of fabric character, and the case is analagous to that of a dyeing which may lose colour in washing without staining the adjacent white.

In conclusion it would appear reasonable to confine consideration to the testing of fabrics for comparative serviceability to well-defined destructive agencies. Whilst imitative wear tests may offer great difficulties they ought to be possible in certain cases, and must be considered since there is a very real need for them.

THE TESTING OF FABRICS FOR RESISTANCE TO ABRASION

By J. C. Mann, M.A., B.Sc., A.Inst.P.

The problem of devising a machine on which fabrics can be tested for resistance to wear has attracted and is attracting the attention of technologists in various parts of the world. Numerous workers in this field of research have devised machines and put them forward as general wear testers. Most of the published work, however, merely describes machines by means of which it has been possible to place several fabrics consistently in a certain order, as determined by their ability to withstand the test. What the authors have not done is to show that these fabrics are placed in the same order when judged by their ability to withstand normal wear. In very few instances, do the sponsors of the machines restrict the type of wear they claim to imitate ; this, alone, suggests how superficially the problem has been tackled.

When it is considered how diverse are the uses to which any particular fabric is put, and, further, how vastly more diverse are the uses to which different fabrics are put, some of the general reasons for the difficulties inherent in the problem immediately become obvious. There are many different types of wear and any attempt to devise a general wear tester is an attempt to make one machine imitate several very different processes.

But, even if we concentrate on any particular type of wear, the mechanism involved is complicated in so far as many factors must be considered. For this reason, one simplification of the problem which has been generally adopted is to study the resistance of fabrics to abrasion, instead of to wear in general, as abrasion is probably the most important single factor in any type of wear.

Such an investigation has been carried out on two knitted fabrics, used almost exclusively for ladies' underclothes, which were submitted so that their relative wearing qualities could be tested. During the investigation, five machines were made, in all of which, with the exception of one in which bending of the fabrics was introduced, the only factor in wear to which the fabrics were subjected was abrasion. The type of abrasion imparted by the various machines was very similar, in that the abrasive material was either a fine grade emery cloth or carborundum ; so fine that the fabrics were able to withstand fairly long periods of rubbing. The machines included both rotary and reciprocating abrasion testers.

The degree of abrasion was estimated by measuring the strength of the material before and after abrasion. As the fabrics tested were knitted fabrics, the tests were carried out on a Mullen Bursting Tester. The relative amount of abrasion was measured by means of a revolution counter or a stop watch.

Before considering the results of the tests carried out on these abrasion testers, it may be well to consider a point which does not appear to have been realised sufficiently by advocates of imitative wear testing. When two fabrics are made up into garments and their wearing qualities compared in normal use, one of two results may be deduced from the observations made ; either fabric A always wears better than fabric B or fabric A sometimes wears better than fabric B (equality in wear being a particular case of the second alternative). In so far as the latter statement implies that the

wearing qualities of the fabrics depend on the conditions of wear and are therefore variable, then no attempt need be made to devise a single laboratory machine to imitate the wearing qualities of these fabrics. Any attempt, therefore, to construct a machine in the laboratory for comparative tests which are to be used to forecast relative wearing qualities in normal use, tacitly assumes that the relative wearing qualities of the fabrics to be tested are independent of the conditions of wear. This being so, it must be assumed that, of the two knitted fabrics under consideration, fabric A must always (or at least in general) wear better than fabric B or vice versa ; but a glance at the summary of results obtained on the five different machines showed the absolute lack of unanimity one way or the other.

In spite of the similarity in the type of abrasion to which the fabrics were subjected, analysis of the results obtained by testing the two fabrics on each machine in turn showed: (1) Definitely contradictory results were obtained from machine to machine, e.g., whereas one machine showed consistently that fabric A withstood abrasion three times as well as fabric B, another machine showed just as consistently that fabric B withstood abrasion five times as well as fabric A.

(2) Using any one machine, contradictory results were obtained by slight modifications in the conditions of test, e.g., by rubbing the fabric in one direction only instead of in both directions, by altering the pressure of the abrasive material on the sample, etc. (3) Contradictory results were obtained according as the fabrics were rubbed wale-ways or course-ways.

The laboratory tests showed not only (*a*) that fabric A withstood abrasion better than fabric B, and (*b*) that the reverse was true, but also, (*c*) that there was no essential difference between the two. No data were available as to the relative wearing qualities of the fabrics, and so it was proposed to have the fabrics made up into ladies' underclothes and to issue one of each type of fabric to girl workers in the mill. However, the difficulties involved in a controlled study of wear by this method were found to be too great and the project was abandoned. The net result was that there was no evidence to discredit any one laboratory result in favour of another.

Although abrasion is obviously a very important factor in wear, it is not in itself the simple action it might at first sight appear to be, as was shown by the different results obtained according as the fabric was abraded wale-ways or course-ways, according as the abrasion was of a rotary or reciprocating type or as the abrasive action in the latter instance was in one direction or in both directions. All these types of abrasion are probably present in actual wear, but there is no evidence to indicate in what proportion they appear. In so far as the different types of abrasion gave different results, it was therefore impossible to forecast the results in actual wear.

The problem is rendered still more complicated by the fact that all the abrasives used in the above experiments were of the carborundum or emery type ; other types were employed, for example, with a smoother action. But to extend the work in this direction would not have rendered any real assistance, as sufficient is not known about the mechanism of wear to determine which type of abrasion is the fairest to employ.

Again, even if it were possible to determine the correct type of abrasion to employ, the action of this abrasion is practically certain to depend on the conditions under which it is used. In other words, the effect of the abrasion

present in actual wear will probably depend on whether the heat generated is dissipated or not, on the amount of moisture present in the fabric, on the presence or absence of perspiration, on the pressure of the abrasive on the fabric, on the fit of the garment, on whether static electricity is generated or not, etc. Hence, not only must the correct type of abrasive be chosen, but it must be used under the correct conditions. In the present state of our knowledge, it is practically impossible to determine when this state of affairs has been achieved.

There are therefore two main difficulties in imitative wear testing, even when this testing is restricted, as it must be, to one particular type of wear. The first is ignorance of the mechanism of wear and the second, the difficulty of obtaining scientifically reliable data on the relative wearing qualities of fabrics.

By attempting to evolve a wear tester whose results can be correlated with actual wear, an attempt has virtually been made to imitate a process about which very little is known, and in that sense, the problem is being approached from an entirely wrong angle. Admittedly, the chief factors in wear (e.g., abrasion, bending, etc.) are known, but what is not known is their relative importance and the conditions under which they act. The scientific method of attacking the problem would be to study carefully the mechanism of wear, decide on the chief factors to be considered, their relative importance, etc., and in the light of that knowledge, construct a machine to copy the essential factors in their proper relation to one another. Unfortunately, it is difficult to see how this can be done until some method of obtaining a numerical estimate of " actual wear " can be devised.

If the second difficulty can be overcome to such an extent that it is possible to arrange a dozen or more fabrics in order from the point of view of resistance to wear, there is one last hope for the imitative wear tester. Having arranged his fabrics in order, he can try to devise, by hit-and-miss methods, a machine which places the fabrics in exactly that same order when tested in the laboratory. Then he might be able to foretell, with a fair degree of accuracy, how a new fabric should stand up to exactly the same type of wear as that withstood by his original selection.

THE SERVICEABILITY OF FABRICS

By W. J. Hall

As Dr. Peirce has shown, the results of the mechanical testing of textile materials with the object of foretelling serviceability always fall far short of the ideal. It must not be assumed, however, that the shortcomings are due entirely to the limitations or imperfections of the methods of testing. It is frequently the case that more information could be extracted from the tests that are made. In this short note it is proposed to discuss one example to show that from a study of the tensile test for yarn, more detailed than that normally made, valuable conclusions can be drawn.

The successful production of continuous filament rayon yarns, particularly of the acetate and cuprammonium varieties, was naturally followed by intense efforts to make rayon cloths similar to those hitherto produced from natural silk yarns. In some cases there was little or no difficulty, and no radical departures from the practice in the production of the natural silk fabrics were necessary. In crêpe fabrics the intrinsic differences between natural silk and rayon are contrasted and emphasized to such an extent that natural silk and rayon crêpes really fall into two distinct categories. Rayon crêpes at present cannot compete with those made from natural silk.

Perfectly straightforward routine tests of the strength, in the warp and weft directions, showed that rayon crêpes, though weak in comparison with natural silk crêpes of similar weight, were sufficiently strong to meet the normal requirements in garments. The difference between the strength of the fabric in the warp direction and in that of the weft is very pronounced owing to the great diminution in strength of continuous filament rayon yarn consequent upon the insertion of a very high degree of twist. It will be generally agreed that this lack of " squareness " does not make for soundness and durability in a fabric. Usually the warp strength is about twice that of the weft, though in some cases it may be four times as strong. It is difficult to see how such an objectionable feature can be overcome since the disparity between the strength in the two directions follows inevitably from the construction which is essential to the distinctive properties and appearance of fabrics of this class.

When such fabrics develop the fault which can be very aptly described as " blisters," shown in Fig. 1, they are no longer serviceable. It appears in parts of garments subject to undue tensions or to rubbing. The periodic return to fashion of tightly fitting sleeves raises a crop of complaints of this nature. No ironing or other treatment will restore the original appearance. Yet no rupture of the yarns, warp or weft, has taken place. The breaking loads, either of the yarns tested as such or of the fabrics, can therefore give no clue to the source of the trouble. The tensile test, however, does provide the complete explanation of the development of this fault.

Fig. 2 gives typical autographic load-extension curves for the continuous filament rayon yarns which constitute the warp and weft of a crêpe fabric. The warp yarn has only about 2 turns per inch, whilst that of the weft is over 50 turns per inch. Though of similar type there are important differences between these curves. Since, as already observed, no breakage of the yarns occurs, the explanation of the fault must be sought in the initial portions of the curves. The warp yarn exhibits a fairly well defined elastic limit A, that is, if the load applied does not exceed AD the yarn contracts

to its original dimensions on removal of the load. For the highly twisted weft yarn the elastic limit is much less marked and the initial approximately straight part of the curve is complicated by the high twist. On removal of the load the contraction is rarely complete. Consider now a cloth containing these yarns subjected to stress BE less than that corresponding to the elastic limit of the warp yarn but above that of the weft yarn. The consequent extensions, as examination of the diagram shows, are enormously different in the two yarns. The warp yarn can contract but the weft yarn is permanently stretched and must therefore cause the "blisters" seen in Fig. 1.

Of course, the complete investigation of a fault of this nature demands the examination of the autographic load and extension diagrams given by the cloth test, but these are necessarily more complex than yarn curves. Further, the properties of natural silk and rayon have to be contrasted in order to explain why the fault rarely appears in natural silk crêpes. But perhaps it is sufficient to show that a more detailed examination of the results of the established tests is of considerable importance. The only conclusion that would be drawn from this examination was that the fault is largely inevitable and that the risks could be mitigated by cutting sleeves, etc., the "wrong way" of the fabric.

Fig. 1 (× 2)

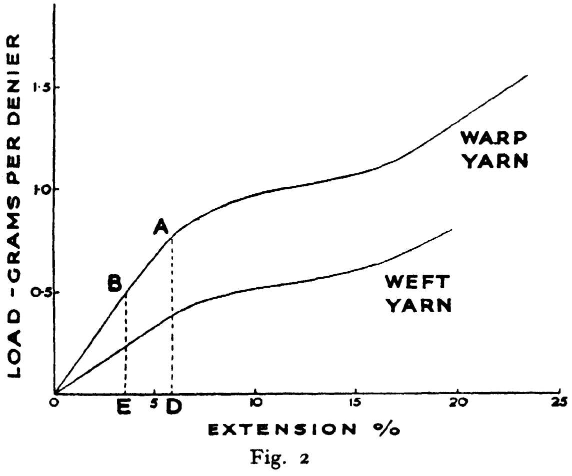

LOAD - GRAMS PER DENIER
1·5
1·0
0·5
A
B
WARP
YARN
WEFT
YARN
0
E
5
D
10
15
20
25
EXTENSION %

Fig. 2

TESTING AND THE SERVICEABILITY OF FABRICS

By J. Guilfoyle Williams.

Fabrics are always being subjected to the test of actual usage. When a customer complains that a material has not been satisfactory the explanation may be one, or a combination of, the following causes :—

(*a*) Some defective qualities of the fabric in comparison with the usual materials of its type.

(*b*) Some unusually severe conditions arising in use or washing. This will include defects in making up such as faulty cutting, poor sewing, or wrongly fitting articles.

(*c*) A mistaken idea on the part of the customer of the service which can be expected from a certain type of fabric. This will include the use of unsuitable materials for the conditions involved, such as loaded silks or rubbered fabrics for use in the tropics.

Thus from the careful investigation of complaints it should be possible to secure data indicating whether colours are likely to be too fugitive, or fabrics too weak, or too readily affected by rubbing wear, for particular conditions of use or for general serviceability.

This paper is based on twelve years' experience in charge of the Merchandise Research Laboratory of Selfridges. The purpose of the Laboratory is to give help in the selection of satisfaction-giving merchandise. At a very early stage of the work the value of information to be gained from the investigation of complaints was realised. When the lower limit for qualities is known the factor of safety for satisfaction-giving qualities can be estimated.

The degree of significance to be attached to data obtained from the investigation of complaints must vary very widely. This twelve years of experience and the examination of, say, six thousand cases of complaint, has not given sufficient data for the satisfactory statistical treatment of the results. The provisional standards which have been adopted have, however, had to withstand the test of application in the following years, and have suffered the modifications necessitated by increasing experience. The author detests the term " expert," but in the present position no excuse is made when more or less bare statements of opinion are given. It is only in this manner that his experience can be published, and of some use to others. As the value of complaints has been mentioned at the beginning of this paper, it is now essential to remove the impression commonly held that a line of textile merchandise must be satisfactory when complaints are negligible or very few in number.

The policy of Selfridges is to encourage any dissatisfied customer to complain. In view of the enormous range of merchandise and the multitude of transactions it is of course inevitable that some unsatisfactory goods should be sold. It is surprising how loath is the customer to complain. Defective merchandise can be divided into three groups of increasing faultiness. In the first class are those likely to prove unsatisfactory, and giving a just cause for complaint. Experience indicates that in this group about one customer per hundred will complain. In the second group are those very likely to prove unsatisfactory early in use, and which will give very good grounds for complaint. In this group about three per hundred will complain. The third group consists of those certain to be seriously unsatisfactory early

in use, and constituting merchandise which is unfit for sale. In this group of exceptionally low quality only fifteen per hundred of customers are likely to complain.

In general, about half the complaints received are due to faults in the merchandise and the other half are due to wrong usage, accidents, etc. In considering the reluctance of the customer to complain it will be realised that if two similar complaints are received against a line of merchandise within a short period, one can be almost sure that the merchandise is at fault in some way. With fabrics the common causes of failure in serviceability are the following :—colour-fastness, shrinkage, strength, thread slippage in the fabric, and effects of rubbing wear. As this is a brief paper prepared at short notice, these subjects cannot be dealt with as completely as is desirable. The subject of colour-fastness will not be discussed. The methods used, and the interpretation placed on the results, are available in a contribution entitled " Requirements of Colour Fastness in Actual Use," which was printed in the *Textile Manufacturer* for August, 1933.

Shrinkage means the decrease in width or length or both of a fabric. Strains in a fabric remain set for practical purposes while the material is air-dry under ordinary conditions. Should the fabric become damp a slow reversion to the unstrained size occurs. If the fabric is immersed in water the reversion is more rapid, and it is still more rapid in a hot solution of soap. The strains are also released in the process of steam pressing. The tests used are simple. A piece of fabric, preferably at least 10 inches square, is marked with white or coloured sewing cotton to give width and length measurements. These marks are about 1 inch from either side. The measurements are to the nearest millimetre. For shrinkage in pressing the sample is covered with a very damp cloth and smoothed with a 5 lb. hot iron. Measurements are made and the process is repeated until no further shrinkage occurs. The sample is allowed to condition overnight, and the measurements are then made giving the shrinkage. For shrinkage on wetting the sample is first given a washing in warm tap water if any significant amounts of dressing are present. It is then immersed in a beaker containing a 0·3 per cent. solution of soap in water at about 40° C. The beaker is left in a warm place for at least two hours, after which the sample is removed, rinsed, squeezed as dry as possible in towels, and allowed to dry while laid flat. The sample is next smoothed on an ironing board, or a pad of cotton sheeting, and measured. This gives the shrinkage in the " ironed dry " state. The sample is now wetted in water, squeezed as dry as possible in towels, and ironed until dry. The fabric is now allowed to condition for several hours, or preferably over-night, and the measurements taken are used to calculate the shrinkage in the " ironed damp " state. This is a damper condition than that usual in hand ironing, but the results are about equivalent to that on fabric removed direct from the hydro-extractor and then smoothed. The shrinkage of fabrics in the " ironed dry " state is usually more than in the " ironed damp " state. In a number of complaints of shrinkage it is found that if the fabric is given the " ironed damp " treatment the shrinkage disappears, or becomes negligible. This, for instance, often applies to fabrics with crêpe yarns.

Suppose that the degree of shrinkage which has caused complaint from the customer is determined, and that a graph be made showing the number of complaints at the various degrees of shrinkage. With increasing degree

of shrinkage the tendency to complain will increase rapidly, and so the curve should rise steeply. But those who order the stretching out of fabrics in the finishing have consciences, which will become the more troubled the greater the amount of stretching given to the fabric. Thus fabrics with high shrinkages will be less common than those with low shrinkages, and so the rate of rise of the curve will be somewhat decreased. Moreover there will be a degree of shrinkage which will make repeat sales of the fabrics very unlikely, and the effects will be to reduce the numbers of such fabrics to a very serious degree, so that the rarity of high shrinkage fabrics will lead to a fall in the frequency curve.

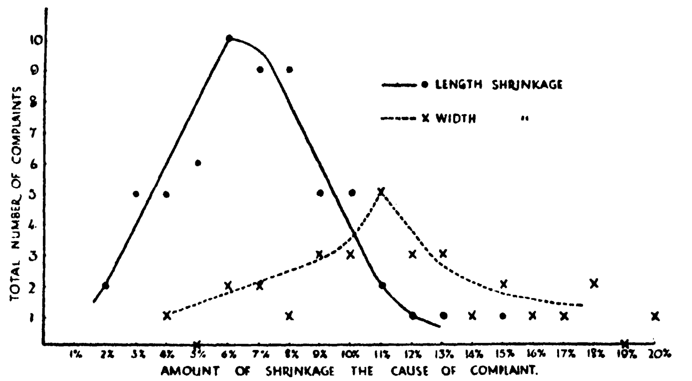


FIG I.

Number of complaints of shrinkage against woven fabrics for clothing and amount of shrinkage.

In Fig. 1 is a graph, giving the number of complaints from customers plotted against the degree of shrinkage which gave rise to the complaint. All these are stretch-recovery shrinkages on woven fabrics used for clothing purposes. No apology is made for the few cases available, for even these few have taken four or five years to collect. It would be ideal to have separate curves for, say, shirtings, blouse fabrics, overalls, night-wear, etc., but the only way the limited data can be treated is to use it in bulk. Notice how anticipations are realised in these curves. From them one can infer that, though length stretching gives more yardage to sell, it is also more objectionable than stretching in the width. One can also infer that any stretching of over 6 per cent. in length is very objectionable to the customer, and that any stretching of over 11 per cent. in width is also objectionable.

As a general standard the author reports that shrinkage of over 5 per cent. in width or length is excessive. This amounts to 1 in. on a sleeve of 20 in. length ; to 2¼ in. on a frock 45 in. in length ; and to 3½ in. on a curtain of 70 in. length. It is impossible, however, to adopt the same standard for all fabrics, and for instance on a shirting a shrinkage of over 3 per cent. would be regarded as too high, while on a crêpe wool dress fabric a width shrinkage of over 5 per cent. may not be objectionable. In passing, one may note that on Fig. 1 those fabrics with width shrinkages of 15-20 per cent. were wool dress fabrics, and the shrinkages are on the damp pressing which is a necessary part of dress-making.

The assessment of the serviceability of a fabric must include shrinkage tests. The effects of shrinkage are most likely to expose the fabric to greater tensions in wear, and to make it probable that where surfaces are

rubbing together the rubbing will be between taut fabrics. In all the welter of discussion about wear and wear-testing, one thing is certain; that is, that the rate of wear on taut fabric is very many times that on slack fabric, so far as clothing is concerned. A fabric with a low shrinkage "ironed damp" and a high shrinkage "ironed dry" can be improved in serviceability. Alter it to one that stretches slightly when "ironed damp," so giving a lower shrinkage in the "ironed dry" state. Drying of fabrics with a hot hand-iron is a long business, and when it is necessary, in order to remove shrinkage, it cannot be popular with the housewife.

In concluding the subject of shrinkage one must refer to the occasional crab-finishing of fabrics. After washing the fabric increases in width to a considerable extent, and decreases in length. The fit of a frock after this has happened needs little imagination. To the onlooker it may be a comedy; to the user with little money it is a tragedy.

In the making of fabrics with special attention to lightness in weight, novelty in structure, or cheapness in price, the strength is likely to suffer. It is clear that, at some point, the strength of the material will not be sufficient to resist the stresses which must occur in use or washing. The fabric is then unsuitable for sale.

The tensile strength test used by the author is the grab test. The strip of fabric is about 6 in. in width and it is grabbed by the jaws of the machine, these being 4 in. in width and also about 4 in. apart. This test is closer to conditions of use than the strip test. The bursting strength is determined with a Mullen Jumbo tester, using a thin rubber diaphragm to remove, for practical purposes, the back pressure error which would occur if thick diaphragms were used on extensible materials.

For the Textile Institute Conference of 1932, the author prepared a paper on the strength requirements of fabrics for satisfaction-giving properties in conditions of ordinary use. It was thought that according to the type of fabric, and the conditions of use, there would be a more or less characteristic zone of strength at which tearing would occur in use. The knowledge of this zone would give a means of assessing the margin of strength on a fabric available to resist the various factors of deterioration in wear. With similar fabrics the amount of this margin would be proportional to the life the fabric could be expected to give in use. The procedure then adopted was to test a considerable number of worn-out fabrics for strength in the air-dry state. The details are given in the *Journal*. It will suffice here to note that it appeared that with a very wide range of fabrics used under very diverse conditions the risk of tearing in use became serious when the tensile strength was below 40 lbs. Subsequent to this the author has, whenever occasion permitted, made measurements of the tensile and bursting strengths of merchandise returned by customers with complaints of tearing. Many cases of tearing occurred with the fabric in a wet state, and so it was realised that the determination of the strength when wet was an essential in all strength tests.

The frequency of the complaints with the strengths given to the nearest 5 lbs. are shown in Figs. 2 and 3. Unfortunately the collection of about five years does not give enough data to give curves with obvious and unquestionable interpretations. Naturally, in the actual examination, some results were of greater significance than others. For particular interpretation one can only give the conclusions drawn to date, which are used as

provisional standards in the assessing of the merits of fabrics for particular purposes, and for the expressing of opinions on complaints. The strengths that will be given are the high values of zones of risk ; above these strengths the risk of tearing or bursting is small, and below them the risk rapidly increases. Moreover, the risks only apply to ordinary types of fabrics,

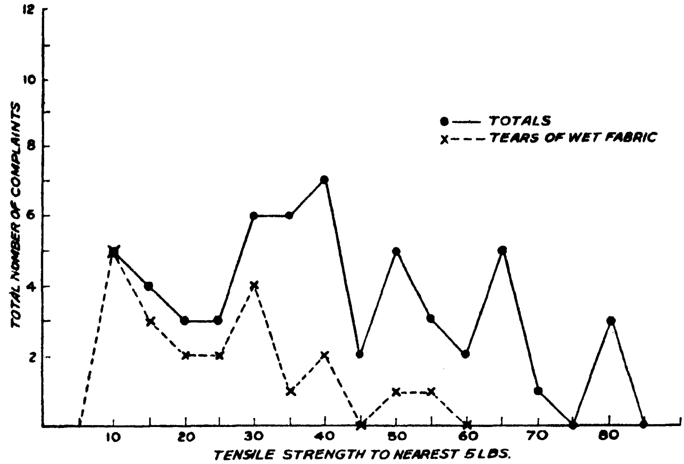


FIG 2.

Tensile strength of fabrics which tore in use.

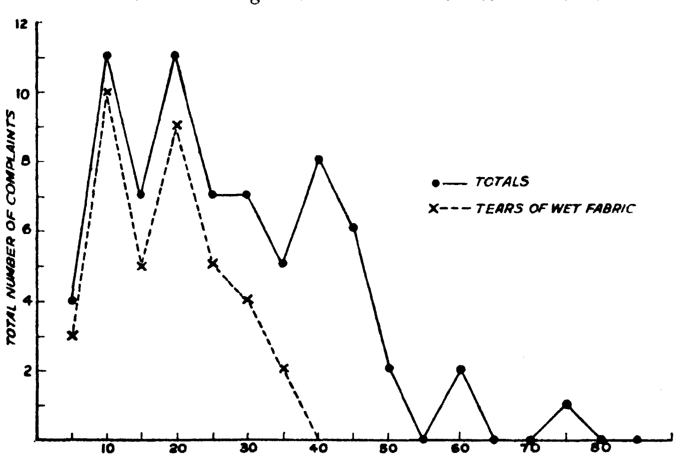


FIG 3.

Bursting strength of fabrics which tore in use.

and so the data must be applied with a proper proportion of common sense. For instance, for ordinary use the sheer, single strand silk stockings are clearly too weak ; but owing to their quality they receive special and very careful use. The common sense person does not make a close-fitting frock on the basis of a rayon net, though if this is done the strength of the material makes it possible to foretell the consequences with a high degree of probability.

The maximum stress occurring on fabrics in ordinary conditions of use for clothing is in night-wear. Here one part of the fabric will be held down

by the weight of the body, and the full effect of bodily movements may act on the fabric. Fabrics with a tensile strength of over 65 lbs. or a bursting strength of over 50 lbs. per sq. in., are not likely to tear in ordinary use. Any damage is likely to be the result of some accident which has imposed an excessive stress on the fabric. Fabrics with tensile strengths of over 80 lbs. or bursting strengths of over 75 lbs. are likely to resist most accidental stresses.

When the tensile strength is between 40 and 65 lbs., or the bursting strength is between 40 and 50 lbs. per sq. in., the fabric is likely to tear in use as night-wear, and it may tear in conditions of severe ordinary use (as, say, in a tightly-fitting garment of comparatively inelastic material).

In Figs. 2 and 3 the number of complaints due to damage when wet is shown as well as the total number (air-dry and wet) of complaints. When the wet strength is below 30 lbs. tensile or bursting there is risk of tearing in ordinary laundering. If the strengths are below 20 lbs. tensile or bursting the risk of damage is considerable. In passing, it may be noted that the numerical correspondence of the tensile strengths and bursting strengths is of course just an accidental feature of using the 4 in. grab test. It should also be observed that the bursting strength is a far less reliable measure than the tensile strength. It is given because, in many cases, it is all that can be determined on small samples of fabric available, or on articles the subject of complaint.

With tensile or bursting strengths between 25 and 40 lbs. fabrics are likely to tear with the ordinary stresses in use. A number of light weight wool novelty fabrics have to be rejected because the strength is too low. Fabrics with tensile or bursting strengths below 25 lbs. are too weak to withstand the ordinary conditions ot use and washing ; while if the strength is below 15 lbs. they are likely to tear even in careful washing treatments.

It will be noted that no figures are given with relation to the stretching of fabrics under tensile or bursting stresses. Undoubtedly the less elastic a fabric the greater is the risk of tearing in the zones of strength previously indicated. If a dress fabric had a weft tensile strength of 40 lbs. and a width increase of 5 per cent. at this tension it would be an undesirable material ; with a width extension of 10 per cent. the risks of dissatisfaction would be very much reduced ; with an extension of 15 per cent. the fabric would not be likely to reach this degree of extension in ordinary wear, and in default of better strength similar material being available, it could be accepted as reasonable merchandise for sale to the customer.

For those who care to use them, these strength data will give some guidance in the designing of fabrics intended to be serviceable to the user. What factor of safety is to be allowed is the problem for the maker of the material, and later for the persons who select the material for sale on the basis of tests.

Thread slippage in fabrics may occur at seams or in the body of the fabric. In the first case it is produced by tension on the seams, and in the second case by a type of sliding rub on the material. It has become more common in recent years owing to the making of lighter and cheaper fabrics. It is most common with silk and rayon fabrics, and does not occur frequently with cotton or wool materials. The distribution found in about eighty cases of complaint was about 45 per cent. of the fabrics were silk, 45 per cent. were rayon, 7½ per cent. wool, and 2½ per cent. were cotton.

A method of measurement for slippage is the amount of opening occurring at a seam when tension is applied. In general this measurement is satisfactory. It would be desirable however, if some other measurement, giving numerical results, could be devised to supplement the test. This second test should submit fabric, held taut, to a sliding rub to give slippage in the body of the material, and should give some measure of this slippage.

The method of test used by the author is to take the average of five measurements across the total width of a zone of slippage at a seam, the measurement being made while the fabric is still under tension. The seam used is the machine-sewn single type, with fifteen stitches per inch, and turnings of $1\frac{1}{2}$ inches of fabric. The test piece has a width of 5 or 6 inches, and the slippage is measured at 4 inch grab tensions of 20 lbs., 40 lbs., and 60 lbs. Tests are done on original fabric, and on material that has been washed. The washing is essential because in many fabrics the slippage increases very considerably owing to the removal of finishing substances.

When trouble occurs with slippage in a fabric it may be due to the fabric being of such structure that it slips too easily, or it may be due to faulty making up such as inadequate turnings in seams, too few stitches per inch, or it may be due to some unusually severe tensions, or rubbing conditions,

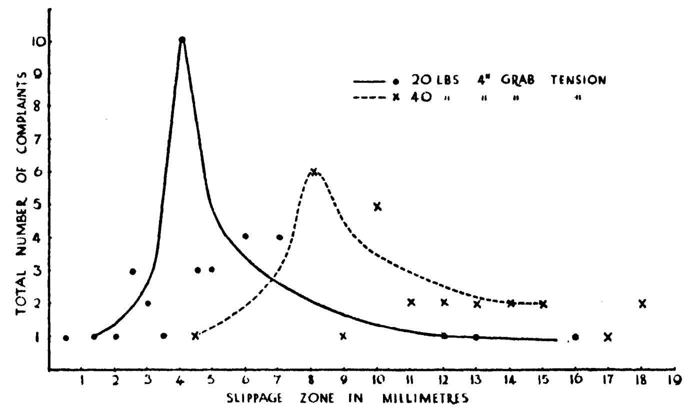


FIG 4.

Number of complaints of slippage in body of fabric and zone of slippage found on test.

in use. For guidance in the selection of fabrics and in the interpretation of test results some standard is therefore very desirable. The most common trouble is slippage at seams. Owing to the many variable factors it has been found that the tabulation of measurements on complaints of this type gives no useful indication. From the consideration of a number of complaints the author, several years ago, adopted as his provisional standard that slippage should be regarded as excessive if it was 5 mm. or over at 20 lbs. tension, or 10 mms. or over at 40 lbs. tension. Where slippage has occurred in the body of the fabric the only factor will have been rubbing in use or washing. The results of investigation of complaints is shown in Fig. 4. The factors that will influence the type of curve have been discussed as a preliminary to Fig. 1, dealing with the frequency of shrinkage complaints. It will be noted that the same type of curve is obtained. It appears that slippage of 4 mm. or over at 20 lbs. tension, and of 8 mm. or over at 40 lbs. tension is excessive from the point of view of slippage in the body of the fabric. This standard is the one now used for slippage generally.

Just as with strength tests, the degree of stretching of the fabric under tension is of importance in assessing the risk of dissatisfaction due to slippage. It has been well said by Peirce that no testing machine can show on its dial an answer to problems of serviceability, and that a trained judgment is required to give the interpretation of test results. The suggestions in this paper are only to aid the trained judgment, not to replace it. It will be seen that tests for the service-giving qualities of a fabric should include a slippage test. If the fabric is one that slips excessively it is deceptive to improve its qualities by some finish which is removed in the first cleaning treatment. The fabric can be improved by putting more twist into the yarns, or more ends or picks into the fabric, or by using heavier yarns.

The common complaint of rubbing wear is not the development of holes or weakness in the fabric, but the disturbance of the surface of the cloth in use. With some dress fabrics and flannel suitings the surface rubs up into tufts and the cloth becomes unsightly, or the nap rubs away and discloses patches of the woven fabric. This disclosing of the woven fabric is most objectionable in some wool union cloths for the undyed state of the cotton yarns makes them very apparent. The rubbing wear is nearly always due to cloth rubbing on cloth. Simple tests of this nature are used when necessary, and they will reproduce the condition of the complaint in somewhere between 50 and 5,000 rubs. As experience has not been sufficient to make any suggestions of provisional standards there is no point in giving details of the method used.

One can feel happy about a testing method if it gives similar results to those found in actual use, or if the results can be found to have some simple relation to the usage tests on fabrics. As the author has no experience of the rubbing tests using mineral abrasives, so strongly denounced by Peirce, his opinions are of restricted value. Clothing which has been varnished to make it hard is outside his experience, so the failure for varnished healds is no proof that the test may not give significant results in relation to some types of clothing fabrics.

One may remark, however, that rubbing wear tests should be made on fabrics at various tensions, and with various degrees of humidity up to the actual wet state. Rubbing wear while wet must occur during washing, and will also occur at times in ordinary use. On one occasion the author examined some imitation leather cloth made by a surface of wool adhering to a rubbered fabric. This had proved excellent in rubbing wear in the air-dry condition. When rubbing in the wet state was tried the serious limitation of the material was at once disclosed. Tests must also be made on fabric which has been submitted to appropriate cleaning processes, for the finishers' condition of the material does not endure for the service life of the fabric. If the loss of strength is measured after wear testing the data on strengths given in this paper will indicate suitable end-points.

In concluding this paper there is one more test that must be mentioned. With some fabrics a permanent stretching of the yarns will occur with the moderate tensions occurring in use. This commonly leads to cockling of the fabric where it has been somewhat tight fitting, as say on the fore-arms of the sleeves of frocks and blouses. The permanent stretching of the whole fabric will lead to sagging, and garments with permanent bulges at the seat or the knees are unserviceable to the ordinary person. The problem particularly affects rayon fabrics, and the cockling is most common with fabrics woven with crêpe yarns. The testing should of course be on wet fabric as well as air-dry fabric.

THE WEARABILITY OF FABRICS—TESTING FROM THE POINT OF VIEW OF THE LARGE CONSUMER

By W. PRITCHARD, A.T.I.

(L.M.S. Research Department, Textile Section)

My first reason for entering this discussion is a peculiar one and refers to a mosquito bite. Some ten days ago I was on my way to the Office and whilst passing a doctor's residence I was stung on the cheek by a mosquito. Whether the doctor keeps a supply of these insects and releases them to catch the unwary I do not know, but he certainly has caught me as one of his patients. The development of the bite was very rapid and for several days I have been confined to the house with erysipelas, by no means a picture to be admired. It was in this state I received the Technical Editor's request for a contribution and it did at once occur to me that I might get rid of some of the venom in my system in this particular way.

Unfortunately, the first advance copy to arrive was that very provocative one written by Dr. Peirce, which blasted all known means of testing as being absolutely useless in assessing serviceability. One can congratulate Dr. Peirce on such a paper by remarking that it is always much more difficult to write against one's own convictions than for those one favours. Still, it was unfortunate, because I happen to be the Head of the Textile Testing Section of the largest industrial undertaking in the world, the L.M.S. This Section is attached to the only Railway Research Department in the world. You are to have a visit on Friday from the Head of this Research Department, Sir Harold Hartley, K.B.E., etc., who is to give the Mather Lecture.

It was with a much bandaged and swollen head that I decided to join in the debate from a purchaser's point of view. I could visualise papers from the academic point of view, also from the manufacturer's standpoint, and I could see a probable dearth of opinions from the purchaser's side, which after all, is the only side to matter.

My mind traversed the ground over and over again that should present standards of testing be abolished as being without value, what could we substitute to obtain quick and satisfactory results. My contribution, therefore, is testing to determine serviceability.

The London Midland and Scottish Railway Company are purchasers of textiles to the extent of three quarters of a million pounds per annum. Every fibre of commercial value is used in some form of raw or manufactured state. In our tender forms we show more than a thousand different items, for which specifications are provided. The range is tremendous and some of you who have had an opportunity of going through our Laboratories in the Research Department at Derby will have appreciated the variety and scope of the work we do. You will also have appreciated the necessity of standard tests to enable material to be passed quickly into use. I have already lectured in different centres on "Textiles used by Railways," so that I do not propose to repeat them, but their number and uses are legion.

The L.M.S. provide uniform clothing in some form for about 100,000 men, at a cost approaching £300,000 per annum. The cloths purchased by the Company for making up into garments are Public Bodies Standards and I am wondering how any conclusion could be reached if we accept Dr. Peirce's theory that behaviour in service is the only satisfactory method of determining

reliable data and simple tests relating to structure, dye, strength, etc., etc., are of no avail. I cannot but presume that the august body of textile manufacturers, technologists and scientists who gave us what is known and accepted as The Public Bodies Standards of Cloths, looked into all the physical, chemical and wearing properties before appending their signatures to that momentous document and that the woolsorter provided the proper blends of English and Colonial wool. The spinner decided the counts and qualities, twist, etc., of the yarns. The weaving manager selected a weave that would stand the wear necessary and desirable. The dyer and finisher provided those solid and sound colours, gave it just the milling, cropping and finishing required for the particular cloth in hand. If this was not done we have been tricked, and I venture to suggest that one of the prisons in Yorkshire which H.M. Government closed some time ago, owing to the dearth of bogus cloth dealers, should be re-opened to entertain the members of that Standards Committee, if any be still alive. It is in the realm of possibility that their guilty conscience may have brought about their early death. I gather this will suit my Lancashire friends, but here in this county the Government has not only closed prisons, but mills have been closed by the score, whilst Yorkshire is crying out for more and more mills. I prefer to leave the two counties to argue the merits of the respective cases.

A system of testing must be in existence by means of which the value of a cloth can be quickly assessed, otherwise what of the economic position? If payment is only to be made when the garment has been under practical test for a period to determine its reliability in service, the economic situation would be one of chaos. Long date credit would be necessary and this would follow all down the long line from manufacturer to farmer producing the raw wool. Such a system would be the means of increasing the prices of fabrics considerably.

The present methods of testing, as adopted by Public Testing Houses like the Manchester Chamber of Commerce, The Bradford Conditioning House, large Corporations like the L.M.S. or firms like Messrs. Tootal Broadhurst & Lee, are generally admitted to be sound. The experience of many distinguished men engaged in the different phases of textile technology has been placed at the disposal of the general public, and for this we are particularly grateful. The Universities and Technical Schools in the centres of the great textile industries have in their syllabus the testing of textiles in all stages of manufacture, so that the student can be acquainted with the faults he may later encounter. As a student at Bradford in the days of Professor Aldred Barker, one of the founders of the Textile Institute, I can testify that testing was by no means the least item in a well-planned curriculum.

If these ready means of testing are not satisfactory, where do they fail? The Court to-day accepts the findings of an authorised testing house and it is well known that men have been sent to the gallows in recent years through the identification of minute fibres or fabric found on an accused man, or as an exhibit in the case.

The standardisation of testing is a most desirable thing but it cannot be said that present methods have failed to give some lead as to the serviceability of cloths under test.

Before leaving this part of the subject may I say one word on testing generally. As head of a testing department one is often met with the accusation that the methods employed are too severe, that we are too

critical, and no allowance is made for the margin of human error which has to be met in every walk of life. My answer to number one is to the effect that all tests carried out are standard, made under controlled temperature and humidity conditions and such as are generally recognised. That we are too critical one cannot admit. We do not exercise any more severity in examining a parcel of cloth than you would do in examining a purchase for your own homes. With regard to the third, it will be agreed by most manufacturers that they receive more help and assistance from the man who has been trained in testing, who has had the experience of practical work in university, college, school or mill, than from one who has had no training at all but happens to have been selected as buyer or head of a testing department for special reasons.

Testing, in my opinion, is of the greatest value to the sound efficient manufacturer, and the more strict it is, the more he should thank his customer, because he knows that the cheap price and low quality of unscrupulous competitors will have no chance so far as his own products are concerned. Testing of a satisfactory character protects the reputable manufacturer and is a means of keeping up quality and reasonable standards of workmanship.

There is, however, a growing tendency for manufacturers to produce a fabric to the price quoted rather than to the standard pattern and/or specification, with the obvious result that testing becomes more exacting and more severe. As purchasers we appear to be a target for manufacturers in periods of both bad and good trade. When times are difficult and purchasing restricted, competition becomes frightfully keen and we are faced, as I have stated, with materials made to fit the price. On the other hand, when trade is good we find manufacturers passing fabrics in which count, quality and workmanship are inferior, knowing that, at worst, a slight reduction in price may be asked for rather than wait for a replacement. This is not fair trading, and whilst the pillars of the Manchester Exchange would not be sufficient to carry out the sentence on substitute cloth manufacturers proposed by Mr. Whittaker, the columns seen on every hoarding depicting a great beverage would not accommodate all those one would like to see suspended for foisting on purchasers cloths well known to deviate from the standard. Another point of a purchaser's view in regard to standard cloths may be stressed. The Army, Navy, Air Force, Police, Tramways, Railways and generally speaking all uniformed staff in public bodies are allowed fixed issues of clothing. It is, therefore, necessary that standards of cloth should be provided which will give the life and service necessary, but it is also expedient, on account of expense, that the quality of the fabrics should not be so much superior to outlast to any extent the period for which they are issued. In the first place the men retain their old clothing, and secondly, whatever the condition they have to be renewed at the agreed time of replacement. The cloths thus provided are the result of actual serviceability in regard to wear, plus laboratory tests.

My next point is in regard to specifications. Cloths have been designed and specifications provided to meet those fabrics from a testing point of view. If the tests imposed compare favourably with the specification figures there can surely be no argument that we are not getting what we set out to buy. If such figures cannot be accepted as being a fair indication of quality, the whole subject of testing falls to the ground.

A typical specification for a woollen cloth for uniform clothing embraces the following:—

Width.
Weight per yard.
Threads per inch, Warp and Weft.
Breaking Load (pieces 6⅝", 7" between the jaws).
Dye (nature of).
Maximum vegetable fibre allowed (if any).
Shrinkage per yard (Warp and Weft).
Fastness to Fugitometer Test (100 hours exposure).
Outside exposure for fading.
Rubs to Wear Test on L.I.R.A. Machine (not specified at present being in an experimental stage).

In addition to the above there are laboratory tests for quality of fibre and yarn, counts of yarn, twist, chemical tests for fastness of dye. Then we have store tests of perching the material for weaving faults, thick yarns, thin places, broken ends and picks, uneven dyeing, etc.

Having carried out all these tests what more is there to find out about the cloth? A practical test could not have revealed more, in fact not so much. If the practical test of a serge suit was carried out in an office which was sunless and not affected by fumes or abnormal atmospheric conditions the test would not be nearly so severe as the laboratory examination quoted above. A test carried out in an open yard with a vitiated atmosphere, plenty of sun, light and air, would more approximate the tests imposed on the cloth.

What do we expect from the tests a cloth must undergo before being passed for use?

The weight per yard is a general guide that the construction of the cloth is in accord with the specification, and that the wearing qualities will approximate to the standard. The threads per inch (warp and weft) show that the yarns employed are of the right dimensions to produce the cloth asked for. The breaking load gives a general indication that the quality of the fibre employed, the twist of the yarns, the dyeing and finishing operations are satisfactory. The shrinkage points to the fact that no undue stretching has taken place. The fastness to exposure in the Fugitometer for 100 hours gives a fairly definite result that the cloth will withstand the action of air and sun. Outside exposure in cases on the roof of a building is an exacting test for any cloth, but the time it takes is against such a test except as supplementary to other tests. The number of rubs required to wear out a fabric is not taken as a definite indication of the wearing properties of a cloth, but when tested by the side of the standard pattern under similar conditions has a comparative value. The machine used is the L.I.R.A. production and can be considered only in an experimental stage so far as assessing values are concerned.

The laboratory tests for quality of fibre, counts and qualities of yarn, twist in yarns, chemical tests to determine fibre and fastness of dye, all have a certain value in proving the quality of fabrics.

Indeed it can be said that without the laboratory tests the work of passing cloths for use would come to a standstill. All the tests imposed have a relationship to serviceability of fabrics in regard to wear.

The examination over the perch for defects not ascertainable otherwise is a final check. Here one finds blemishes such as bars, due to differing weft, or yarns which differ slightly chemically or physically, stains due to various causes, oil, grease, paint, dye, badly creased cloths due to inefficient pressing, mildew owing to bad storage, thick and thin yarns, weaving defects, uneven edges and a host of small matters.

With the completion of the whole of the tests both chemical and physical one has some idea of the wearability of the fabric.

So far as wearability is concerned it is necessary to divide fabrics into two classes, viz., those required for outer wear and those for underwear. In considering outerwear some consideration must be given to the work to be performed by the wearer. As an example, a goods porter handling boxes, parcels, trunks, etc. will require a cloth to withstand considerable friction on the front of his clothing, and for this purpose a thick woollen cloth with a certain amount of surface is necessary, otherwise a threadbare appearance will be the result after very limited wear. In addition strength of material is essential to enable lifting heavy weights. As a contrast, for a man in a supervisory grade where manual labour is not required, a worsted cloth, of a lighter weight would be sufficient for the purpose.

For underwear a different set of conditions obtains. Resistance to washing, perspiration and friction are the chief factors, with construction and fastness of dye closely following.

These tests can be satisfactorily applied in the laboratory and serviceability generally determined.

An entirely new line of thought in regard to both men's and women's clothing has taken shape in recent years. The modern man and woman, particularly the younger generations, require many changes of garments rather than clothing designed to wear for lengthy periods. To meet this change multiple shops are providing suits and dresses at ridiculously low prices and such is the turnover that large dividends are being paid. One has only to see the number of clothes the modern young lady takes for her annual seaside holiday to appreciate this fact. How can one assess serviceability in these cases ? In the case of the young lady attraction is serviceability. If she has succeeded in drawing attention to herself by the number, colour and design of the clothes she has purchased and worn she will consider the money well spent, and the height of service will be self and not the length of time the garments will last.

The young man in flannel trousers and sports coats of startling checks, squares and colours, with heavily oiled hair, will brave all the elements of the weather, and defy shrinkage, if it is the last word in design and shade and picks him out as one of the *knuts*. A new pair of trousers or a new sports coat will be nothing if it earns the admiration of the opposite sex. How then can we assess serviceability in these cases ? Length of service is not the first essential of purchase, but smartness and snappiness, so we have to find new methods in defining the word serviceability.

In the case of uniforms for public services, testing plus wear will be the determining factor. Clothing for men and women must be divided into two sections. Firstly, for younger people, style plus design count for serviceability without question of cost or length of wear. Secondly, for older men and women whose wardrobe is restricted and quality plus price plus service must determine serviceability. What standards can we adopt

to meet all these cases. It would be impossible to find suitable ones for all needs. Whilst public taste is the great factor of the types of cloth to be used; whilst artificial fabrics are replacing natural ones; whilst the appeal to the eye is more important than the purse or length of service, then serviceability becomes a problem of difficulty because no standards exist that will meet the complexity of public demands.

There is one other point to which attention should be drawn and that is misuse affecting serviceability. The misuse may be one of a number of things. It may be due to laundering. The market is flooded at the moment with preparations advertising the fact that laborious washing is a thing of the past and if the named concoction is used the clothing or fabrics wash themselves. The powders may be harmless if the directions are carried out implicitly, but in nine cases out of ten this is not done. Many complaints of loss of colour, shrinkage and tendering of fabrics are brought to our notice. In nearly every case we find that the damage is due to the misuse of strong washing preparations. Another constantly recurring complaint is that of garments being returned as defective owing to small holes appearing in the cloth. Investigation proves that acid from accumulators is usually the cause. Complaints are often received that the serge used in the making of trousers has proved defective owing to inferior quality being supplied, the failure usually affecting the seat and fork of the garment. When this is looked into we generally find that the man cycles to and from work and also does much cycling in his spare time. Here is a case where cloth is required to withstand double the ordinary wear, yet if used legitimately is quite equal to the service required. These cases can be multiplied indefinitely in fabrics other than for clothing. One can mention in passing the tendering of window curtain materials in railway carriages due to the action of light, sun and condensation. This deterioration has now been overcome by purchasing material that will resist condensation. Again the tendering of coloured borders of dinner napkins due to the action of the dye on the fibres has caused a revision to be made in the type of napkin purchased.

The crimping of artificial silk bedspreads after laundering has also been a source of trouble.

The question of union cloths is also one of difficulty. I quote cotton and linen union cloths as an example. One knows that cheapness is the underlying feature of this type of fabric, yet every student knows that the lives of linen and cotton differ considerably and that one will wear out much more quickly than the other. Twenty-five years ago flax warp and hemp weft canvas was brought into existence as a standard product for railway waggon covers and accepted as being a good combination. Recent research work has proved that after a certain period the deterioration of the hemp is much more rapid than the flax.

I mention these latter cases to show the lack of knowledge manufacturers possess of the serviceability of the fabrics they supply. In these days of research one would expect that all such factors would be taken into consideration before a cloth was put on the market.

How then can we fix standards of serviceability, first for the misuse of fabrics and secondly for the lack of essential knowledge in the manufacture of fabrics. There seems to be a long way to go—despite our advertising that British textiles are the best in the world—before we arrive

at an understanding of proper combinations of fibres, designs, dyes, and other features demanded for a perfect cloth.

In bringing my remarks to a conclusion may my final words be on the lines that the present system of testing is the best means of proving serviceability. Whilst admitting that all the factors of fabric service cannot be covered by chemical, physical or practical tests owing to the wide divergence of conditions of service, due to wearer, environment or differences in the fabrics themselves, yet they are the only methods by which quick results can be obtained. The textile chemist, physicist, or the practical tester has long since rejected the rule of thumb methods of determining the quality of a fabric, and are using standard tests which have been evolved by recognised students of scientific research in the various stages of manufacture. This work is being fostered by the Textile Institute, whose members month by month provide for all branches of the industry the scientific knowledge they have acquired.

The breakdown of fabrics under tests I have mentioned—and which are so well known—lead to research problems of a minor or major character, which benefit the industry as a whole. The interchange of knowledge thus acquired, which brings together into a composite body the technical, practical, manufacturing and consuming interests, must be to the common good.

DISCUSSION.

JUNE 10th, 1937.

THE SERVICEABILTY OF FABRICS—APPEARANCE AND HANDLE.

F. SCHOLEFIELD, Esq., M.Sc., F.I.C., F.T.I., in the Chair.

Mr. F. Scholefield expressed his appreciation of the honour which had been conferred upon him in the invitation to preside over the first meeting of the Conference. His consciousness of his own unworthiness for this office was largely off-set by the pleasure he felt in presiding over a meeting to be addressed by Mr. C. M. Whittaker, for whom personally he had had a very high regard for many years, and for whose work, especially upon problems of viscose dyeing and of the behaviour of dyed viscose and cotton materials to light, he had great admiration.

Mr. Whittaker deserved the thanks of dyers in general for having given time and energy to the technical investigations of textile problems, and for having published the results; and his achievement in this respect was all the more remarkable when it was remembered that he had done a very large amount of public work for the industry on many councils and committees, including the Colour Users' Association, the Fastness Tests Committee of the Society of Dyers and Colourists, The Dermatitis Committee and so on.

The Chairman referred to the title of Mr. Whittaker's paper and of the general subject for discussion. It was remarkable that in a language so full of synonyms as the English language, it was not easy to find a shorter word having the sense of "serviceability." He did not regard "wearability" as appropriate since it might be regarded as meaning the property or quality of being wearable, and that was not in the strict sense a subject they were to discuss that day. The Chairman then introduced Mr. Whittaker.

Mr. C. M. Whittaker (Manchester) gave a short account of the subject discussed in his paper. He showed samples in illustration of some of the points made therein.

Mr. Binns (Bradford) outlined briefly the substance of his paper which appears above. He illustrated his remarks by reference to samples of cloth and tops.

Mr. A. E. Delph (Bocking) said that there could be no idea of the trained technical man rendering unnecessary the judgment of the buyer. The function of the latter was to keep his finger on the pulse of public taste. The technical man could doubtless help the buyer in certain ways but his principal work was really to interpret the findings of the scientists engaged on fundamental research, and to put them into a form applicable in industry and distribution.

Dr. Peirce (Manchester) said: "To link up the discussion with that of to-morrow, it may be useful to distinguish the several aspects of the subject. I interpreted the word 'wearability' in the same sense as the Chairman, to mean the state of being suitable to wear, as distinct from the durability of that state in wear. The technical value of a material may be estimated by the service given, as the integrated product of the quality during service and the duration of service. The quality may be considered as the sum of the appeal and performance minus the defects.

"By appeal, I mean the qualities dependent on taste, on which personal judgment is primary. We may try to analyse and understand these judgments in terms of physical tests, but cannot pretend to guide, correct or control them thus. In this field, great credit is due to Mr. Binns for his pioneering work and a most interesting and valuable line of work is opening up, in the study of thresholds of perception, analysis of choice, sales statistics, etc., in terms of physical measurements, interpreted by Gestalt psychology.

" By performance, I mean the qualities dependent on physical behaviour, strength, waterproofness, permeability, etc. on which tests are primary. Personal judgment in such matters is no more than a stop-gap to supplement an imperfect scheme of tests and theory. Physically, fabric may be regarded as a boundary and its performance has two aspects: the strength, by which the boundary is maintained; and the efficiency of the fabric in maintaining different physical conditions on its two sides.

" Under defects, I class all admittedly faulty places that must be cut out or that would make seconds. Cost is the primary consideration here and commercial practice the guide. What would be a defect in a falling market will sail through on a rising one. Testing finds its use here on the grounds of its impartiality, to resolve differences of opinion between parties that appeal to it. Defects also cover the local damage that may bring to an end the useful life of a garment, even though its general condition is still serviceable in appeal and performance."

Mr. E. Farrell (Southport) said that in order to have some idea of the mentality of buyers of textile materials he accompanied his wife on several occasions when she went out shopping in Southport, and she never raised the question as to how long a thing would last. Women were the biggest buyers of textile materials, and if some of those present that day depended on serviceability alone he greatly feared they would soon be out of work. Trade depended largely on the number of times a woman changed her mind, which she can do without giving offence. His wife did not attach as much importance to " How long will it wear ? " as to " How does it look when I wear it ? " The actual question of serviceability arose more frequently with men's apparel than with women's wear.

Mr. J. G. Williams (London) said: " A previous speaker has stated that women whilst shopping do not make enquiries about the lasting qualities of textiles. It is quite true that in fashion and novelty fabrics the first considerations are the appearance and handle and similar obvious qualities. The achievement of these qualities is nearly always obtained at the expense of part of the service-giving qualities, and if the maximum of appeal is sought, attention should nevertheless be paid to ensuring that the minimum of serviceability is not passed. In a paper he had presented to this Conference some guidance is given on the minimum qualities required.

" The importance of appearance and handle in the selling of textiles is very great. Studies of this aspect are very important. A number of years ago I made a few tests in this direction. Samples were tested and arranged in an order of test merit. The samples were then inspected and handled by retail buyers and under-buyers, and also by a number of persons representing the ordinary customer. On winceyettes and silk crêpes de chine the judgments of the retail buyers, etc. were in agreement with those of the public. But on cotton bed-sheets the retail buyers, etc. were in most cases very interested in the weight of the sheets, and picked them up to assess the weight; their order of preference was considerably affected by this factor. On the other hand the public did not pick up the sheets to assess the weight; their judgment was based on inspection and handle only.

" The idea is to have goods which have both a high appeal and a high utility value. In the Selfridge Group we are developing lines of standard merchandise using the general trade name of ' Durance ' to indicate that serviceability is the special characteristic. In the selection of these lines a large number of samples are secured from many sources and tested fully in the laboratory. The goods are then divided into three groups of good, medium and poor quality. If any lines have some special attraction in price or appearance and do not come into the ' good ' group the manufacturer is given the test results together with suggestions for the improvement of his material. Then the goods selected on the basis of utility are submitted to a committee of the buyers of departments

which will be selling the goods. This committee selects the one which has the best " selling appeal." Suggestions may be made from the laboratory or from the committee for the improvement of the merchandise in either utility or appeal.

" This process is one that gives the lines a good start on the selling of satisfaction to the customer both at the time of purchase and subsequently. With the lines launched it is open to suppliers to offer better values if they desire to take part in contracts for the following year's buying.

" The application of some similar testing of utility and appeal cannot be anything but helpful to all manufacturers of textiles."

Dr. Cunliffe (Leeds) summarised the paper contributed by him and printed above.

Mr. A. J. Hall (Nottingham) expressed the view that a greater sense of fairness should be brought into the relations between the purchasing public and the manufacturer of textile materials. Most manufacturers and processers, such as dyers and finishers, were fully aware that many textile materials could be made far more serviceable and satisfactory to the consumer, if it were possible to increase the wholesale purchase prices by a small amount, say 5 per cent. or 3d. on a single garment costing 5/-. He confidently believed that the public would be willing to give this extra price if it were convinced that the increase represented real additional value and increased serviceability.

At the present time, the manufacturer finds it extremely difficult to secure higher prices for his products. The tendency is towards lower and lower prices which can be met only by reducing the real quality of the goods. One of the principal reasons for this undesirable state of affairs is the inability of the public to feel confident that higher prices represent extra value and better qualities. This lack of confidence is frequently due to bitter experience that goods are not up to the standards claimed for them. From his own limited shopping experience, he was certain that " truth in advertising " was not yet with us.

If this desirable confidence between producer and consumer could be established and means brought into existence for ensuring that all textile materials conformed to the standards claimed for them, the public would willingly pay the small extra price necessary in order to secure higher quality. Unfortunately, the retailers were not content to pass on these increases without adding to them unduly. Mutual confidence between producer and consumer would be better for all. Research workers, technologists, and craftsmen would then be able to obtain their just rewards, and skill in manufacture would steadily increase. The production of shoddy goods might still temporarily prove a profitable occupation. In the interests of all branches of the textile industry and in that of the technologist in particular, the public should be educated to understand and realise that a small increase in cost would permit of an increase in quality out of all proportion to itself.

Mr. McCotter (Belfast) read the paper submitted by his colleague Mr. H. B. Bradley.

Professor Davis (University College, Nottingham), said that there was a tendency for textile investigators to deprecate their own achievements in devising methods of testing. The wide recognition now accorded to many of these methods of testing was a testimonial to their contributions to the developments of the textile industry. He quoted one example in support which was that of the fading test on textiles by the Fade-ometer. This was often queried as to its exact scientific value. In practice, however, it had resulted in raising the standards of dyeing in many branches of textiles, for dyers whose products were unable to stand up to the required number of hours exposure to the fading lamp were quickly forced to use improved types of dyestuffs.

More recently the testing of textiles had acquired an obvious commercial value as is shown by the frequency with which official tests on textiles were now used for advertising purposes. This was a development which called for the vigilance

of the appropriate section of the Textile Institute. It was well known that the status of a particular textile could be assessed only by a series of tests, no single test being fully comprehensive. Some of these tests appeared at first sight to be extremely favourable, but they required to be balanced against others which did not appear quite so favourable. The undiscriminate use of selected favourable tests for advertising was often misleading and contrary to the canons of experimental and scientific accuracy.

In assessing serviceability, particular attention was directed to the reduction of the life of a garment by various agencies such as rubbing of a hard collar on a shirt, or the abrasion of a seamed sleeve against the seamed body portion of a garment, as at the armpit. In these two instances, the fabric broke down at such points long before the textile properties of the main fabric had deteriorated, and many otherwise excellent garments in this way came to an untimely end. It was of little avail that the fabric manufacturer produced super qualities, if the garments made from the cloths were to be destroyed after a relatively short period of wear by adventitious agencies of this character. In this connection improved technique of seaming or sewing garments was of considerable interest to the manufacturer. In certain branches of the knitting industry for example, one type of join was excellent for a garment having normal and quiet usage in wear, but the same type of join was entirely unsuitable in a garment used for athletic pursuits, where it was subjected to sudden thrusts and jerks. In athletic garments, a slimmer and cheaper seam having greater resilience, could often be substituted with immensely improved results in durability. In recent years makers of bathing costumes had greatly improved the serviceability of these articles by the adoption of a type of seam or join capable of withstanding the contracting influence of salt water, which by the earlier system of seaming made the sewing threads tight and liable to break quickly.

Professor Davis pointed to the tendency for various research institutions to consider the serviceability and performance of the fabrics in which they were mainly interested to the exclusion of others. He advocated some means of assessing the value of garments when worn together, as for example, a knitted garment next to the skin, the cotton intermediate and the outer woollen garment. As regards appearance, he considered that perhaps manufacturers had gone too far in considering the appearance of the fabric before its primary function of keeping the body warm. In certain types of footwear for example the cult of the fine gauge had caused some types of footwear to be completely deficient in the property of cushioning the feet in walking. It was also considered by medical authorities that too fine gauge hose and thin textiles gave insufficient protection against insect bites which appear to have increased in virulence during the past decade. He similarly deprecated the continual trend towards ever lighter weight garments, which in coldest months of winter were often sadly lacking in adequate heat retention.

Mr. Lomax (Nottingham) expressed his appreciation of the great service Mr. Whittaker had rendered in calling attention to unnecessary and ridiculous standards. If, in the operation of dyeing, corset fabrics or the cotton tops of silk stockings showed stripes instead of being perfectly level, the serviceability was in no way impaired. The dyer, however great his effort, could not always produce perfect results. Such faults should not be considered sufficient ground for rejection.

Mr. W. Kershaw (Manchester) : I have read Mr. Whittaker's paper with very great interest, and I agree in the main with the arguments put forward. He has, I think, purposely laid excessive stress on certain aspects of the problem. I speak as one engaged in the finishing section of the industry, having contact with the production side.

We are always attempting to develop something new in the finishing line. In addition we control many processes by the testing of large numbers of samples and carry out investigations necessary in the elucidation of faults.

Technically I maintain that the textile industry is a reasonably efficient one. Take the case of the cotton industry, with its 2,000 million yards export trade, and an equal yardage in the home trade ; the numbers of technologists engaged on the " dispute " side are very small and Court cases are practically non-existent.

We are concerned at this Conference with the technical, rather than with the merchanting side of the industry. The problems of selling and marketing are large enough for a Conference dealing solely with these problems.

Now I would like to say a few words on one phase of Mr. Whittaker's paper, and that is the " gradual deterioration in the quality, and therefore wearability of many textiles in recent times." I have been in the industry for a sufficient length of time to have seen the change-over from the Oxford shirting to poplins—first the two-fold, fine count variety, then the two-fold and single, and finally the single-single. I have witnessed also the change that has taken place in the voile trade, from the limited demand of the fine two-fold to the very large production of single-single. Is this the type of deterioration that is in Mr. Whittaker's mind ? If so, it has a redeeming feature, having created employment in many directions, spinning, manufacturing and finishing.

I am prepared to say that any fabric, the yarns of which have survived the strains and stresses of sizing, weaving (and what can be woven can be finished)—is a wearable commodity in one market or another, and that it will remain so until every Hottentot is a millionaire. A slump may be the harvest time for Woolworths', but the finishing or " Veredlung " of a " deteriorated " fabric is a delight to the finisher.

Wearability is a relative term, and in my opinion the hard-wearing properties of fabrics of a generation ago are not desired by the present generation. If it were so, we should be clothed in moleskins and corduroy. Nowadays, we can use the term " fashion life," and we understand its meaning.

As this Conference is debating wearability, serviceability, and bearing in mind the various tests now in use to foretell these properties, it is obvious that the methods we have at our disposal do not give us the complete picture. We can determine strength, elongation, resistance to abrasion, resistance to washing, shrinking, bursting, tearing, but tests for handle, draping properties, appearance, are lacking, and these are significant properties, difficult to express in arithmetical terms. It is the combination of these properties which determines " Textile Quality."

Now " Textile Quality " depends on a number of properties, some definable, others not so easily defined, and in the ordinary course of development to produce new fabrics, new effects, etc., it is sometimes desirable to sacrifice certain properties in order to produce a fabric of desirable characteristics. As an example, take the case of aniline black dyed goods. It is accepted that there is a considerable reduction in tensile strength, due to the dyeing process. In the bleaching and finishing of linen damasks, there is a substantial loss of weight and corresponding loss in tensile strength, but the textile quality is enormously enhanced. The same applies to linen dress goods, now so popular. In modifying the properties of certain types of artificial silk fabrics, by chemical means, to produce matt effects or subdued lustre, and so give desirable properties in the light of prevailing fashion, there is reduction in strength. In pigmented rayons also, properties as determined by tests, are modified, and as a final example, in the production of an organdie, there are considerable modifications, as revealed by mechanical tests, but it is undeniable that textile quality has been produced.

The point I wish to bring out in quoting the above examples, is that it is more important to consider textile quality, as a whole, rather than lay too much importance on individual characteristics, as revealed by individual tests.

Many of the points in Mr. Whittaker's paper deal with marketing, admittedly a very important subject. As we are at present organised, it is difficult to define what is meant by correct marketing, and it appears to me that in instances

quoted, faulty marketing is apparent, and has created unnecessary difficulties. There are many in this audience, more capable of dealing with this subject than I am.

It is likely that the Textile Institute will, in the near future, play an important part in the new developments that are taking place with regard to the question of standards, and complicated as the problem is, I think we can see daylight with advantages to the industry as a whole.

With reference to the technical developments of recent date, and further developments on the horizon, I visualize that even the dungaree mentioned by Mr. Whittaker may still be allowed to retain its China Clay, but in a much more tightly bound condition, with respect to dusting and also to washing. Modifications in the fused collar field are already on the market, which will have an appeal to that wide market—the World.

In conclusion, one word on the detensioning or preshrinking processes now successfully launched, and in particular to the Sanforizing process, as being the one with which I am most familiar. As you are aware, the testing of the fabrics before and after Sanforizing is a necessary feature in the control of the shrinking process. In one sense, the machine itself is its own detective, as during steaming and drying, faulty bleaching and the presence of deleterious finishing materials are immediately brought to light.

Mr. G. Haigh (Bradford): As merchants are continuously lowering cloths on the worsted side of the ladies' trade in spite of 100 per cent. rise in the price of tops during the last two or three years, manufacturers are definitely required to produce cloths at precisely the same prices as last year's. This demand from the merchant or maker-up is all the stronger because it does not arise from temptation by the manufacturer offering cheaper lines of similar appearance.

On the question of serviceability it is interesting to note, however, from the cloth lowering point of view that a lower quality of wool is not necessarily less serviceable. A very fine 80's short staple wool is in certain circumstances more liable to rubbing up into neps than a lower crossbred yarn.

In another branch of the trade the stepped prices have been reduced approximately a penny per yard. Manufacturers are told by the merchants to allow for the increased percentage profit required by the retailer. Under these conditions in the main serviceability is a factor which can scarcely be considered.

Mr. Whittaker has pointed out one or two examples where exact colour matches, or at any rate cross-matching is not necessary. One cannot but agree with him on these points but his opinion on the furnishing trade where the following two points arise would be appreciated.

1. The furnisher stocks certain quantity of material and if he books an order for a greater length than he has in stock he expects to be able to use the two deliveries in one suite.
2. A customer buys a furnishing fabric to blend with other items in the same room; if this is unreasonably "off" in shade the colour-scheme is spoilt.

Mr. H. C. Barnes (Manchester) said that no one has yet taken up what seems the most controversial of Mr. Whittaker's many valuable points, that of the relation between standards of quality and price. Many manufacturers choose between a policy of aiming at what is assumed to be either a *price* market or a *quality* market. There must, however, be very little trade devoid of price consideration and none of the so-called price trade without quality being taken into account. If such division need be made, the industry as a whole needs both the quality or fine trade, which is a matter of profit, pride, and prestige, and the price market which is bulk trade at fine margins, if any. This distinction between ideas of policy seems clearest in Yorkshire but actually suiting materials for example might be bought at any price from say, 2s. to 30s. a yard. Perhaps a better way of looking at the relationship would be to consider *value*, that is, the

total textile quality, appeal, or wearability to one individual, divided by the price, though this is a very vague quantity. The actual test is surely the competitive ability of a material; whether it will sell against all the temptations to spend the money on other fabrics or anything else. As shown in Mr. Whittaker's references to the cheap stores, the policy of fine margins or "small profits, quick returns" (in more than one sense) has had its successes. Obviously the public forgives defects of quality if the bargain is good enough, much as all, particularly the producer, may regret such lack of character.

The underlying standard is "skill in the art". It is the degree of customary skill in producing from more or less imperfect materials, and usually with the utmost economy in materials, labour, etc., a more or less perfectly "wearable" fabric at a price. What can the consumer or the distributor be expected to know of such standards, which may also rise or decline, or change in character according to a generation's outlook? The consumers and their would-be protectors, the distributors, are somewhat ungrateful to be looking so critically at this gift of producers' skill, and talking of some strict testing of us. It is fair if they will appreciate and pay for "quality" but the standards are the province of the producers who may choose whether to educate the buyers, or discipline themselves. They will naturally look with suspicion on straight-jackets offered by distributors, or even their own too-objectively-minded technologists.

The distributors might discover and describe in detail the nature of demands but they will necessarily have to leave to the producers the problems of any new results that can be obtained, the means of getting them, the standards of quality and the price.

In many cases textile materials are self-tested in the sense that if the materials can be got successfully through spinning, winding, weaving, dyeing, etc., they will be well above the physical requirements in service. The problem is then to reduce the processing strains. One might distinguish between testing for control of processing, and testing for serviceability of the product. The latter is more likely to give rise to errors in suitability of specification or economy of materials.

Mr. W. Crossley (Manchester) said that many speakers have blamed the retail stores, and in particular the retail multiple stores, for many of our present-day troubles and difficulties, and as in most cases I agree with them, I should like, as a finisher, to give another example of how the policy of fixed selling prices is resulting in inferior production in unexpected ways.

A retailer who is still selling his shirts at 4/11d., 7/11d., etc., is not only compelling the merchant to cut his cloth quality, but this merchant is insisting on finishers returning to him a gain in finished length from grey length of 3 per cent. or more. This, of course, results in abnormal shrinkage when the garments are laundered, and it is my view that this practice has largely resulted in the demand for shrunk finishes. It would seem, therefore, that when retailers insist upon and pay extra for shrunk cloths, they are paying for something which has been created by their own folly.

One would reasonably assume from Mr. Whittaker's paper that the "Rigmel" and "Sanforised" shrinking methods are the only successful methods of shrinking in use. This is not so. There are other processes of a natural type which claim to give better results than mechanical shrinking methods. Dr. Peirce has told us that no scientific standards of testing shrinkage yet exist, but the trade is nevertheless suffering from a number of alleged scientific tests. I recently saw a report given under seal by a Chamber of Commerce, in which they stated that a pattern $8\frac{1}{4}''$ long had shrunk 0.3 per cent. in the warp. This represents one-fortieth of an inch, and I think it needs no words of mine to demonstrate the absurdity of this test.

At present, therefore, the practical test of "customer satisfaction" is the only one which really matters, and this is certainly not the exclusive property of any one or two methods of shrinking.

Mr. W. E. King (Bradford Technical College) said that he wished to endorse the remarks put forward by Mr. Binns, respecting " judgment ". He said that he had been closely allied with the lecturer on many occasions in this work, and many of the cloths on which " judgment " tests had been carried had been produced in the College with which he was connected. He could assure the meeting that many of the results obtained by judgment tests on school children were remarkable in their accuracy. He did not wish to suggest, however, that school children were experts in their judgment of fabrics generally, as had been humorously suggested by other speakers. It should be remembered that only one characteristic of judgment was being tested namely, that of " handle ". It was often remarked that very young children and drunken men usually speak the truth, due to some inherent cause. Similarly it might be said that children possessed some inherent quality which enabled them to appreciate fine differences in the handle of fabrics. The judgment of a fabric, however, depended on several characteristics, all of which must be assessed in determining the quality and suitability for the purpose for which the material was intended. It was the correlation of all these factors, giving each its proper share of importance, on which a sound judgment was based, and this could not be expected of young children.

He also suggested that even when a series of tests for any particular fabric had been carried out very thoroughly, it was still necessary for the person who was trying to correlate these results to use judgment, based on his previously accumulated knowledge, in coming to a conclusion. Thus in some ways, the terms " judgment " and " experience " might be said to be synonymous.

Referring to Mr. Farrell's remarks that " on accompanying his wife to purchase a gown, the question of its wearing property was never discussed ", he suggested that had the lady been buying sheets, or blankets, instead of a gown, the wearing quality would probably have been one of the most important factors she would have taken into account. Thus, the dominating property which the customer looked for most probably varied according to the article being purchased, again a question of judgment.

He referred to the remarks of Professor Davis of Nottingham, that an epidemic of insect bites had been an important factor in combating the " stockingless " habit which had been prevalent during recent summers, and that this had stimulated the silk stocking industry. He suggested that the obvious solution of this problem for even greater protection was for ladies to wear wool stockings again. He realised, however, that it was useless for any mere man to suggest that ladies should wear wool stockings, if those made of silk were the fashion. Pride was often painful.

Respecting the paper given by Mr. C. M. Whittaker, he said that he agreed wholeheartedly that the insistence by manufacturers on identical shades, as instanced in woven labels and corset cloths was unnecessary. It was a source of annoyance to the dyer, and increased the cost to the manufacturer.

Although the insistence of identical shades was unnecessary in cases of this kind, it was absolutely essential in other cases. He instanced the case of a 6-cut warp for the making of navy worsted serge piece-dyed. The 6 pieces would come off the loom, and might be sent to the dyer at different times. Eventually all the 6 pieces might be purchased by the same wholesale clothier for making into suits. In this case, the maker up would have his difficulties increased considerably unless all the pieces were identical in shade, and it might result in a suit like Joseph's coat, of many colours.

Another example might be cited of the widely advertised hand-knitting wools at present in use. A lady might purchase what she considered sufficient to complete a garment, only to find that when nearing the end, she is an ounce, or two ounces short, according to the tension used in knitting. She naturally expects to be able to purchase a further supply of identical shade to the first lot, and

if she cannot do so, the garment is ruined. This is a frequent cause of argument between the retailer and the customer.

Thus it is evident that whilst the insistence on identical shades in some cases may be unnecessary, in others it may be of prime importance. In this connection, it would appear that with the growth of multiple tailoring and handknitting, an even greater insistence on the matching of colours may be demanded.

Mr. Dilks (Manchester) mentioned the fact that there were certain important differences in (for example) cotton dress cloths, the cause of which could not be detected by any of the ordinary testing machines in the mill—those that give counts, turns per inch, and so on. These differences must be due to the nature of the cotton used, or to the mode or spinning of both.

Mr. F. C. Harwood (Launderers' Research Association, London) said that Mr. Whittaker had reminded them of the slogan " the customer is always right ". Another, equally popular in some circles, was " the laundry is always wrong ". He wished to point out that the laundry frequently receives more than its fair share of blame. In cases in which it was difficult to allocate the responsibility for faults which did not appear prior to laundering, the launderer usually adopted the course of paying up rather than losing a customer. He referred to Mr. Whittaker's condemnation of the misuse of the term " fadeless ". He thought it very regrettable that the description " unshrinkable " appeared likewise to be applied indiscriminately to all kinds of woollen underwear, regardless of fabric structure or the application of chlorination or other unshrinkable finish. It should be possible safely to assume that woollen garments marked " unshrinkable " can be washed without undue shrinkage by processes which have been proved to be suitable for properly chlorinated goods.

Mr. Petrie (London) pleaded for closer co-operation between the textile and laundry industries. Some of the constructions employed in fabrics intended to withstand repeated laundering, were quite unsuitable.

In regard to the shrinkage problem Professor Morton (Manchester) drew attention to the danger of overlooking the reverse side of the picture. The problem in its wider sense was one of change of dimensions and the question of stretch also came into it. A garment made from unshrinkable material might still prove unserviceable if the nature of the said material were such as to allow it to stretch too easily under the stresses of ordinary wear and laundering. Excessive extensibility could also be the source of much trouble in the making-up operations. expecially if the garment involved the stitching together of fabrics of different extensibilities.

Mr. Farrell commenting upon the shrinkage of garments in laundering, deplored the excessive tensioning of fabric in manufacture which necessitated the use of de-tensioning processes.

Dr. Toy (Manchester) said he would like to express his appreciation of Mr. Whittaker's interesting and stimulating paper. The question of " appeal " and its psychological aspects might form an interesting subject for discussion at some future Conference. A previous speaker had referred to the Shirley Institute as a Court of Appeal. This expression suggested rather too forcibly a legal atmosphere, but he took it as a compliment to the complete impartiality of the Shirley Institute, a characteristic, of course, of all true scientific research organisations.

Mr. Whittaker, in briefly replying to the discussion on his paper, said that the policy advocated by Mr. Barnes is sound within limits, but there is a very definite danger of unsound or rubbishy textiles so disgusting the mass of purchasers that they abstain from buying the particular line of goods altogether with the result that the sound products of similar type suffer as well as the rubbishy. As far as he understood control schemes, they would provide guidance to the

ultimate purchaser between the sound and the unsound fabric, but there would be no suggested prohibition of the production of rubbish.

He accepted Mr. W. Crossley's correction about cloths which would not shrink. His phraseology had been careless as it was well known that if care were taken in the processing and finishing of fabrics so as to avoid stretch, etc., competent designers were able to design fabrics which would not shrink.

His comment on absurd insistence on correct matching in articles for which it was not demanded by the ultimate consumer naturally did not apply to all dyed textiles. As one who dyed large quantities of yarn for the furnishing trade he had a full appreciation of the necessity for exact matching in furnishings so as not to upset the completed colour scheme of a furnished room.

With regard to Mr. Kershaw, he had frequently discussed this subject with him privately, and he felt certain they did not differ widely. He had no objection to the development of cheaper cloths, but he did protest against further and continuous depreciation of a successful cloth, which depreciation was not asked for by the ultimate consumer.

Finally, he must again insist that there are put up between the dyer and manufacturer and the ultimate purchaser absurd standards of matching, etc., which are not demanded by the final consumer, and which the final consumer is not able to appreciate.

DISCUSSION.

JUNE 11th, 1937.

THE SERVICEABILITY OF FABRICS FROM THE POINT OF VIEW OF WEAR.

B H. WILSDON, Esq., M.A., B.Sc., in the Chair

Mr. B. H. Wilsdon, Director of Research of the Wool Industries Research Association, in introducing Dr. Peirce, referred to the wide field which had been covered in the discussions of the previous day. They had travelled from the consideration of test methods which had been the subject of careful investigation, to less well-defined proposals which, like that advocated for the demonstration of the hygienic properties of clothing, might better be described as defining interesting fields for investigation.

At a certain stage in the consideration of a test method, it was necessary to put the question " How will this test be employed if published for general use by the industry ? " Many systematically applied test procedures might be expected to yield informative results if correlated with other data in the hands of experienced workers, but might prove exceedingly dangerous instruments when used without discrimination. The requirements for a satisfactory method of test would therefore appear in different lights when viewed, for instance, from the cloistered security of the Shirley Institute from the angle of the laboratory responsible for control of industrial output or when used by the representatives of the purchaser or retailer. The research worker was faced with the difficulty of getting reliable data on actual performance of materials for correlation with his test results. The industrialist needs for control of his processes, procedures which, above all, must be simple and rapid. "Acceptance tests " must be thoroughly understood and approved by both sides concerned, by the manufacturer as well as by the purchaser.

It was certain that the contributions from each of the three angles must be co-ordinated before a test procedure could with safety be reduced to a written specification. It was a matter for general satisfaction that the Textile Institute was offering its services for this desirable end. The necessity for immediate action was illustrated by a rapidly growing tendency to prostitute for purposes of publicity and advertising, the results of " scientific " test. The remedy was clearly to be sought in the adoption of agreed methods.

Dr. Peirce had written a paper which it had been a delight to read. It was not to be thought that his attitude to textile questions was solely that of the hospital clinician called upon to study only the failures and mal-adjustments of mankind. A recent publication of his, in which a fundamental mathematical study of cloth structure was commenced, was sufficient proof of his wide interests. What might be regarded as a somewhat philosophical view point on matters of testing should provoke just that critical consideration which is so necessary in attempts to assess by test the serviceability of fabrics.

Dr. Peirce, in introducing his paper, said : " My paper was written to be read, rather than heard, and I do not propose either to repeat myself nor to make another lecture, but merely to add a commentary on several points more easily dealt with orally.

" First, I would make some apology for my rather provocative tone, in view of the very good humour of the other contributors. It was my duty to see that discussion was stirred up and I hope to have succeeded in that, without giving offence. The subject is one admitting much difference of opinion and I am not as dogmatic as this introductory paper might suggest.

" Nor am I perhaps quite as dumb as I suggest. I would like to earn my living by an open-air life, hitting golf balls in the sunny fields, but necessity imposes a sedentary one indoors. I would like to discuss all things openly and

freely, but I must respect the confidence reposed in me, by silence on matters of private business. There remains plenty of general interest for frank discussion.

"A third general point is the notion that my paper assails the value of textile testing. Need I say, in view of my job, that it certainly does not. It challenges blind belief in the identity of test results and service experience. Testing has to-day no need for propaganda on such a false basis, but it does need doubt, the soul of science, that exposes unsound assumptions and leads to understanding.

"The main thesis may be put thus: We have on one side service, the actual use of the material, on the other its anatomy, the cause of all its behaviour and the result attained by the producer. Service is the ultimate aim of technical study, anatomy is the common language of producer and consumer and our purpose is to relate these two. That may be done by statistical surveys, but the gap is too large to be bridged directly. That bridge I have divided into two parts: service trials and character tests. Trials are intended to be actual service, under conditions allowing effective observation and measurement. Tests are intended to measure under simple known conditions general characters closely related to anatomy.

"It is possible for a service trial to constitute a valid character test, if the conditions of service happen to be simple and suitable for a test. Such an admission would not invalidate my argument, but it is not easy to find an example. I chose a brake test, having no experience of such, but was later assured by one who had, Mr. Emley of the Bureau of Standards, that it correlated badly with service, in which the conditions are actually far from simple. On the other hand, the carpet test, though crudely imitative, happened to agree well with service. Nevertheless, a successful imitative test is like a beginner's first lucky punt on a horse.

"By imitation, I do not mean the controlled reproduction of observed and measured physical conditions. Such, simplified according to an analytical understanding of the nature of the conditions, provides the proper basis of a character test. Imitation is the attempt to reproduce without analysis, from external appearance, with all the complexity of fortuitous combinations. It may be illustrated by two stories. A Hindu saint used to meditate at sunrise and, disturbed by the demonstrative affection of his cat, tied it to the foot of his bed. Centuries after, each member of his sect tied a cat to the bed after rising and felt that he was following the master. This is the imitation of externals, without the essentials. An Australian gentleman, greatly pleased with a Savile Row suit, sent it to Japan to be copied. Two perfect imitations were returned, each with a carefully darned tear in the trousers. These two dangers always attach to mere imitation—missing the essence and including the fortuitous; but, even if the imitation is formally correct, analysis and understanding are still necessary for true interpretation.

"Another point needing amplification relates to the purpose of testing, which may be research or inspection. Research testing constitutes one part of an investigation on performance, usually to determine the best kind of fabric for a particular purpose. Inspection testing is concerned with deciding whether a sample may be accepted as effectively the same as a standard fabric, already chosen for the intended use by research, experience or both. For inspection, the problem is merely to choose the simplest set of tests that will eliminate the probable and important deviations from the accepted standard. The samples are not tested for serviceability but for identity. It is with research testing that my paper deals."

Mr. Lester (Manchester) summarised briefly the two papers contributed by him. Dealing with the standardisation of methods of testing he thought that in some cases, simplified methods of testing would be necessary for mills, the more thorough tests being carried out in research laboratories.

Professor W. Davis (Nottingham) discussed briefly the results obtained with the abrasion testing machine, developed at Nottingham University College. This machine formed part of the exhibition of wear testing machines in connection with the Conference.

Mr. J. C. Mann (Braintree): In considering the wearability of fabrics many factors are involved and many tests are required. In the short paper I have prepared for this Conference, I have confined myself to one aspect of the problem: the attempt to devise a machine by means of which to forecast how a fabric will stand up to normal wear.

The desirability of such a test is not questioned: it could obviously be of great assistance to manufacturers, salesmen and buyers. Several speakers yesterday stressed the point that when a woman is buying fabrics or garments, one of the questions she never asks is "Will it wear well?" However, the mere fact that she did not ask that question when she did her buying, will not prevent her harbouring a feeling of dissatisfaction if the material does not give the service she is entitled to expect from it. Any test that can assist in the estimation of serviceability is a desirable one. But, unfortunately, the mere desirability of a test does not help to overcome the difficulties involved in its evolution.

I think I can take it as agreed, that a general imitative wear tester is an impossibility: it is not reasonable to expect one machine to imitate several very different processes. But even if we narrow the problem down enormously by considering not only one particular type of wear but merely one factor (abrasion) in that particular type of wear, the problem still remains a complicated one.

In my paper I have discussed briefly the results of abrasion tests on two knitted fabrics, used almost exclusively for ladies' underwear. Whatever else may be said about these results, it can certainly be said that they are comprehensive, as I was able to demonstrate (1) that fabric A withstood abrasion better than fabric B, (2) that fabric B withstood abrasion better than fabric A, and (3) that, as far as their ability to withstand abrasion was concerned, there was no difference at all between the fabrics.

Such results are of no use to a manufacturer as a guide to the most suitable structure, say, for a fabric that will wear well, but an attempt might be made by a salesman to use some of the results. And here we may touch on a point made by our Chairman this morning, when he said that, when considering any test, we must consider, among other things, the use to which that test is to be put. The sense of mental honesty may not be so keenly developed in a salesman as it should be in a scientist, and the former, wanting a selling point for a particular fabric, might take the result that suited him and ignore the others. The point is that, if he told a customer that he could demonstrate by means of an abrasion machine that this particular fabric withstood abrasion better than the other, he would actually be stating a fact and yet he might at the same time be acting dishonestly. He makes the statement implying that the one fabric will wear better than the other, when actually neither he nor anybody else has any idea of the connection between his statement and the relative serviceability of the two fabrics.

It might be said that in my paper, I have adopted a defeatist attitude. In one sense, I have, but not without due cause. So long as I am asked to foretell the relative wearability of two fabrics by means of an imitative wear tester, I feel compelled to say that such a machine cannot yet be devised, for two reasons:—

(1) Insufficient knowledge of the mechanism of wear.

(2) The difficulty of obtaining reliable data on how fabrics withstand "actual wear."

These difficulties in devising a wear tester may be better appreciated by reference to a statement made yesterday by Dr. Cunliffe, that a successful test

for resistance to shrinkage had been evolved. The essential difference between shrinkage and wear (in this connection) is that it is possible to measure shrinkage, but it is not yet possible to measure wear. In evolving a shrinkage tester, various fabrics can be tested on the laboratory machine and the shrinkages measured; the fabrics can then be laundered in the ordinary way several times and again the shrinkages can be measured. It is then a simple matter to decide whether there is any correlation between the laboratory test and actual laundering. In trying to evolve a wear tester, the fabrics can be tested in the laboratory and their relative wear estimated; what cannot yet be done is to estimate their relative serviceability under normal wearing conditions, so that no correlation between laboratory tests and actual wear can in general be established.

I am not condemning abrasion testing as such; what I do object to is the use of abrasion tests to foretell directly the relative resistances of fabrics to normal wear, before there is any justification for correlating laboratory tests with actual experience. Much useful information may be extracted from abrasion tests, provided, in the words of Dr. Peirce, we regard the tests, not as "wear imitation tests", but as "complex character tests".

Mr. W. Pritchard (L.M.S., Research Dept., Derby), giving a brief summary of his paper, stressed the need of testing generally and its great importance to the large consumer of textile materials. The testing of serviceability by observation under the actual conditions of use was quite impracticable. The consumer needed tests to guide his purchases.

Mr. B. H. Wilsdon said that in discussing tests for various characteristics which determined "wearability," it was necessary to consider how they would be used in practice. A procedure which might be found useful in the laboratory, where correlations with other tests and with experience could act as moderating influences, might prove very dangerous in inexperienced hands.

Before a method of test could be regarded as a standard, it must be thoroughly understood in all its implications by both the manufacturer, who would use it for the control of his processes, and by the retailer or user, who might wish to employ it as an acceptance test. Viewed in this light, "Owt was *not* better than nowt!" An empirical procedure used as an acceptance test could result in over-emphasis of a single characteristic and might indirectly cause manufacturers to turn out worse material in efforts to make a good show in this single respect.

The thorough discussion and examination by all interests concerned of procedures to be used in acceptance tests was an essential step in progress towards more effective relationship between consumer and producer. It was encouraging to think that support might be forthcoming which would enable the Institute to discharge this important function for the Textile Industry.

Professor Morton (Manchester): "Since the problem under discussion may be considered from two different points of view, I ought to make it clear that in what I have to say I look upon any wear tests not as a device intended to reproduce faithfully service conditions, but one that can be used simply as a tool with which to investigate the effects, one by one, of the different variables of the cloth complex on its resistance to disintegration by friction. That is, I am thinking in terms of a resesrch test rather than an acceptance test.

"But from either point of view, it seems to me that the question requiring our most urgent attention is: What is the fundamental nature of the disintegration of textiles by friction? Does every kind of surface exercise a rubbing action that is peculiar to itself? Or do all surfaces, or at any rate many different surfaces, exert an action that is fundamentally the same?

"The passage in Dr. Peirce's paper most nearly related to this apsect of the problem occurs just below the middle of page 187 where he describes the abrasion that takes place in service as "a rubbing to and fro that tends to drag the fibres apart by friction and break them only one by one as they become isolated." This may hold good in some instances, but such observations as I have made

indicate that it is by no means true for all. Microscopical examination of cotton fibres taken from the worn parts of discarded articles of clothing such as collars and shirts, as well as of others that have been involved in a laboratory fabric-on-fabric wear test, showed that deterioration had taken place very largely, if not entirely, through an attack on the coherency of the fibres themselves. By some means or other, innumerable small portions of the fibre surface had been torn away, and in a great number of instances the fibre appeared to be in the process of breaking up into spicules about 2 or 3 μ wide and up to about 40 or 50 μ long. Such conditions can scarcely be reconciled with the analogy of the neat-fingered woman untying a knot, unless perchance she had used her finger nails to some good purpose. A more appropriate analogy would be that of a bridge player cutting for deal by drawing a card from a spread out pack, the pack being the fibre and the cards its component parts. He may make his cut in two ways. Either he may take a purchase on the edge of the chosen card by means of his finger nail and so pull it away from its neighbours ; or with his finger he may do it with the aid of friction alone. Either or both of these actions may have been present in the disruption of the fibres I have mentioned.

" Both kinds of action have this in common, that the abrasive exerts a local hold on the fibre, and by means of this hold tries to dislodge it from its normal position. Hence, if my picture of what takes place is correct, the possible reactions to abrasion involve three cohesions : (i) The cohesion between the abrasive and the fibre ; (ii) the cohesion between the fibre and its neighbours ; and (iii) the cohesion between the structural parts of the fibre itself. Destructive action will ensue only if, after taking into account the directions in which the various forces operate, the first of these cohesions is greater than either of the other two. Then, the final nature of the damage done will depend on whether the coherency of the fibre is greater than the coherency of the structure of which it is a part. If it is, the fibre, itself undamaged, will be pulled out of place to form a kind of unwanted nap on the fabric surface. If it is not, either the fibre must break due to longitudinal tension or that part of it which is immediately held by the abrasive must be sheared, peeled, or otherwise torn away from the rest.

" The coherency of the fibre in all its aspects is therefore a matter that requires further investigation.

" In some of my own experiments I have used mineral abrasives of various kinds, and I suspect I am one of those whom Dr. Peirce accuses of having an ' emery complex '. Even so, I hold no special brief for such abrasives. It must not be overlooked however, that they have the not inconsiderable merits of speed and constancy of action, and should not be dismissed without good reason. Dr. Peirce appears to dismiss them on the ground that they exercise a cutting action which may be likened to that of a disc carrying razor blades. Well, I am not yet prepared to accept that parallel, at any rate as applying to all mineral abrasives. While his description is true of some, I do not think it is true of all. In any case, the fact that fibres that have been worn by mineral abrasives show evidence under the microscope of having been cut, cannot alone justify the condemnation of such abrasives, because what appears to be exactly the same kind of cut is to be found in fibres from worn parts of articles of clothing such as collars and shirt cuffs.

" And perhaps it may be pertinent to inquire what after all is the real difference between cutting, and the blunter kind of shear, of the action of which there is abundant evidence in all sorts of woven textiles ? Are we not here again turned back to the fundamental question of fibre coherency ?

" In conclusion, may I suggest that, in wearing experiments which involve the use of an unyielding abrasive surface, the amount of work done may very well prove to be better than the number of rubs as a measure of the amount of wear that has taken place ? "

Mr. P. A. Bentley (Leicester): "Some five years ago Mr. Williams introduced a paper at the Textile Institute Meeting—I am not quite certain where it was held, it may have been Leamington. The title of his paper referred to complaints and errors sent to their store with reference to both woven and knitted fabrics.

"At that meeting, Mr. Williams made certain suggestions, which may be useful both to the distributor and the manufacturer in the shape of the means of testing both woven fabric and knitted goods before they were accepted by the distributor, so that they should know, or have a good idea, of the life of the fabric before retailing.

"He mentioned about the bursting of the selvedge on the heel and toe of knitted socks and stockings, particularly with reference to silk plated socks and stockings, as they had had quite a number returned through being faulty on the selvedge.

"After hearing his remarks on that occasion, I was so impressed that I thought something ought to be done to eliminate these errors, and when I returned to Leicester I was determined to go fully into it and just see what was the cause and what was necessary to eliminate the error.

"I mounted a microscope on the machine so that it was controlling the knitting position, to see just exactly what was taking place during the knitting operation of the heel and toe, particularly with reference to the selvedge. I had a great surprise when I found, on looking through the microscope, that there was quite a cloud of dust, which was fluff from the yarn through being badly treated by the mechanism of the particular type of machine. I am referring in particular to a double cylinder machine of the 'Komet' type.

"The sinkers on a double cylinder machine, when making the heel and toe on the reciprocation, cause the yarn to be crimped or stretched, and then the latches of the needles beat the yarn, causing a further distortion and destroying the yarn during its knitting operation.

"It took something like two years of experiments before we were able to eliminate this error. We have now invented what is known as a 'bluff' sinker, which is operated by a tag on the slider just at the period of making the heel and toe, and consequently raises the yarn out of the hook of the sinker and therefore does not destroy the same.

"Now with regard to woven fabric, I have been looking at two machines which are on exhibition at this Conference. One is invented by Mr. Lester, and one by Prof. Davis, and I am quite sure these two machines would be brought or designed into one machine, which would, to my mind, make one of the most efficient testing machines for measuring the wearability of woven and knitted fabric.

"This is not all however. When you have tested the wearing of the fabric made by these machines, you still have to go further—that is you must have a means of measuring the wear.

"During the War years, in 1916, a machine was designed for measuring articles at 50 to 1 magnification. I was partly responsible for some of the apparatus and the National Physical Laboratory was responsible for the other. This apparatus could be made to measure the wear by testing what takes place on these machines and comparison with standards which would be agreed upon by officials of the Textile Institute, so that the standard would be there for all time."

Mr. Stanbury described very briefly the abrasion testing machine, which embodies the principle of the Deeley oil tester, developed at the Wool Industries Research Association Laboratories.

Mr. H. B. Taylor (Carlisle): This question of the wearability and the serviceability of fabrics has been very ably dealt with by all the previous speakers, yet no reference has so far been made to wool fabrics for ladies' wear; a section of the Textile Industry which I venture to say is one of the largest.

Being the designer and manager of a firm which produces pure wool ladies' mantling and dress goods fabrics I am naturally very interested in this side of

the industry, and would say at once that we often have the complaint (if complaint it is) that our fabrics wear too long. Buyers do not want fabrics to do this, nor do the ladies, who prefer to be sufficiently well dressed and yet to keep up with fashion changes. Thus it would appear that abrasion tests are not required on pure new wool goods especially if the construction be such as to give a compact fabric.

However, not all fabrics are made from pure new wool and this brings me to some research work I did years ago as a student at Leeds University. I refer to research on shoddy. At that time the subject before us to-day was not thought of, and the tests were made for the strength and elongation both on the yarns and the subsequent cloth made from blends of (a) 100 per cent. wool, (b) 75 per cent. wool and 25 per cent. shoddy, (c) 50 per cent. wool and 50 per cent. shoddy, (d) 25 per cent wool and 75 per cent. shoddy. Altogether 5,200 tests were made, and much useful information obtained both from the yarns and the finished fabric. The several lots of yarns were woven as wefts into a cotton warp, each lot of weft being kept separate.

After all the tests were finished sufficient cloth was left to make them up into overcoats, and one interesting point I had the opportunity of noticing was that the lowest quality fabric, which was worn by a brother, who is a farmer, lasted for three years whereas, the one I wore, made from the pure wool lasted only about one year. Thus in the light of recent research this opens out a large field yet to be developed. For instance, would lower quality fabrics with small intersections and good milling properties (making the fibres cohere) during finishing, give as good an abrasive test as a loose pure new wool fabric with little or no milling. Also would the finer wools, i.e. the best quality be as good as a cross bred, etc.

Mr. J. G. Williams (London) : The testing of textiles for serviceability must take into account all the properties of the material. One weak link in the chain may spoil everything. The production of textiles with regard to serviceability should be controlled by some person with the requisite all-round knowledge, or it might be the result of the co-operation of specialists on the various qualities. Whittaker's paper, and my experience, both show that the importance of the dyeing is often not realised, and so merchandise otherwise satisfactory is made of low service value.

The question of low price is of course a very relevant one with regard to serviceability. In this Conference I consider it would be a mistake if we began to argue on economic questions when the technical aspects of the problem require attention more urgently.

Should price be of no consideration, it seems to me that the production of serviceable textiles does not require any great mental effort on the part of the textile technologist. But as the price is lowered the problem becomes one more worthy of his efforts, and calling for greater technical knowledge. One can appreciate that at some point the lowering in price will be too great, and the utmost application of brains and knowledge of the problem will fail to produce any other than unserviceable goods. I do not believe that in any general sense this position has yet been reached. It is also obvious that, once it has been reached, the failure to secure repeat sales of the goods will mean a very early rectification of the position.

This raises the question of the present position of technical knowledge of the qualities required for serviceability. When one consults any technical literature one finds that much of it appears to have been written by people of limited practical experience, and the amount of useful and usable information one can gather on some particular problem is often very small. My experience in searching through textile literature in relation to the testing of merchandise, the significance to be attached to test results, and the requirements for service-

ability, has usually been very disappointing in the amount of positive and useful information obtained.

Information about service qualities is obtained from textiles which have proved unserviceable in use. The information can of course only be gained if such complaints are properly investigated, but little scraps of relevant knowledge will be gained day by day by many textile technologists. Even the very fierce price cutting competitor must have that ideal of the good distributor of " Selling goods that won't come back, to customers who will." Owing to his price cutting he must from time to time find he has goods that do come back, and on which repeat orders are not secured ; he has passed the lower limit in qualities, and data about such fabrics is of value not only to himself but to all technologists. If all these scraps of knowledge were collected the aggregate could be of great help to others in the design of textiles, or in the guidance that could be given in research work.

In the Merchandise Research Laboratory at Selfridges, a part of the work is the testing of textiles in relation to buying, another is the investigation of causes of complaints against textile merchandise, and a small part is the carrying out of quick and rough types of research to bridge over gaps in present knowledge.

After test results have been made on fabrics, the report is abstracted into the columns of a printed sheet. Thus all tests made on rayon marocains are tabulated, and the results of previous work are available for guidance in expressing opinions on present samples. If a similar or better tabulation of test results on fabrics were kept at the Textile Institute, and were available for textile technologists, it would prove on occasions a very great help.

One may initially have very little knowledge of, say the subject of cotton blanketings. After making a fairly comprehensive comparison of samples from a dozen or so different sources, one finds that there is little difficulty in making useful contributions in a discussion about cotton blankets with the so-called experts on this subject. In passing, this brings to mind a useful illustration of price and quality. When we tested various samples submitted for a standard line of cotton blankets, one manufacturer was outstanding with regard to price, but unfortunately also somewhat out-standing in relation to the low strength of his material. Suggestions were made for the improvement of his product, and a more suitable type of blanket was submitted. This was not quite to our satisfaction, but at the third effort the maker was able to meet our requirements. He knew how to make the goods at a low price, but not what was required in the goods. Co-operation produced a blanket satisfactory in price and quality.

The paper submitted to this Conference and printed above is based on the condensed and analysed contents of envelopes dealing with shrinkage, strength, and slippage.

Would it not be very helpful if the Textile Institute had similar files, kept in duplicate ? • I am sure that all technologists would be pleased to send scraps of knowledge that they gather on the various subjects, while not expecting any publication or other form of acknowledgment. All that is required is that a list of the groupings of the file should be widely circulated, and that members should be asked to send notes, abstracts of their reports, cuttings from papers, odds and ends of experience, and so on, for inclusion in the appropriate section. Anyone interested in, say the trouble of the cockling and permanent extension of crêpe yarns in rayon fabrics, could have the duplicate file for perusal. I am sure that the labour of wading through the partial and incomplete data would be well spent for the information which would be gained. As the file extended, or as a member used it for reference purposes, the existing information could be abstracted and condensed, and in time it would probably arrive at a form suitable for publication. For instance, one could hope for papers dealing with the special conditions affecting textiles in use at the Poles or in the Tropics. Some useful indications could be obtained as to the service life given by a shirt in the

contaminated atmosphere of an industrial town, and in the purer atmosphere of some quiet cathedral city.

Had a file of this type been available I do not think that the immense work on colour fastness standards of the Society of Dyers and Colourists would have produced a perspiration test of very limited dubious value. The file would have shown that many of the complaints are due to the effects of salt concentration produced by many wettings with perspiration. The test given takes no account of this factor of salt concentration. Nor would the washing test have been one that gives a useful grading of colour loss on fabrics, and a useless grading of the bleeding. It would have been realised that on a washing test the colour loss is only one of very many factors, and that of these factors bleeding is perhaps the most important.

Then there are the previously mentioned researches which are also filed under a suitable grouping. They are of course far too incomplete for publication. But there is the saying that " Owt is better than nowt," and for instance I would welcome any information, however scrappy, on the effects of light exposure on the Tootal crease-resisting process fabrics.

Doubtless some similar and better systems of filing have been used by the Research Associations, and by the Testing Houses for many years. So much the better ! If the experience from the many different angles is focussed at the Textile Institute, the value of the files will be so much the greater. The wider the cast of the net for information the better will be the resultant catch.

Having launched these suggestions, I now await with great interest the comments which doubtless will be made.

Mr. Lomax (Nottingham) outlined the contents of the paper submitted by him.

Mr. H. C. Barnes (Manchester) dealt briefly with the subject discussed in his paper printed above.

Mr. F. C. Harwood : Dr. Peirce has said that knowledge of character tests is not sufficient, but that it must be supplemented by performance tests. There seems to be agreement, on one point, namely, the difficulty of correlating tests in the laboratory with performance in use. I need not remind you that laundering is a service industry. It is important from our point of view to test fabrics or made-up articles under the actual conditions which are necessary in practice to obtain those articles in such a clean well-finished condition, that they are readily acceptable to the housewife. Here may I point out that washing processes vary very considerably both as to relative proportions of soap and alkaline material used, time, maximum temperature and so forth. Each of these factors has a very important bearing on the life of the fabric and so on its serviceability. Thus whilst a laboratory washing test on some standardised lines on any one particular piece of fabric might be valuable yet the same test applied to a different kind of fabric might be entirely valueless, because of the fact that when made up into a garment that fabric might require an entirely different washing process. Physical variations in any one process are also extremely important. In his paper Dr. Peirce makes the following statement : " Shrinkage is not at all sensitive to details of the machinery, so long as the material is thoroughly wetted out and given a fair amount of mechanical agitation." I have taken this literally, and I find I cannot agree with it. Let me give you just one example.

Suppose we are washing wool goods in a rotary machine fitted with any appliance to give interruption to the motion. We can obtain very marked differences in shrinkage on a test piece by keeping the mechanical movement of the machine and the process time constant, but altering the quantity of the wool goods in the machine. i,e. the dry-weight loading per cubic foot of machine space, or by altering the volume of water put into the machine. Thus a very important determinative factor is the friction of fabric on fabric during the washing process.

Mr. E. J. Poole (Leeds): Much attention and discussion has been focussed upon the measurement of the serviceability of cloth by subjecting the cloth to tests with controlled abrasives.

Whilst Dr. Peirce has not entirely overlooked the factor of the creasing of cloth, I venture to suggest that no complete assessment of serviceability can be made if this factor is ignored.

The properties of fibres other than wool introduced into wool mixture fabrics will, of course, modify the relations or behaviour of the cloth in proportion to the amount contained in the fabric. The property of creasing is undoubtedly of great importance in wool fabrics and particularly in worsted cloths, and a satisfactory method of measuring creasing would, therefore, be of definite value to the manufacturer and consumer. Two aspects of creasing must be distinguished when dealing with wool materials, viz.:

(a) the liability of the cloth to accidental creasing as in wear.

(b) the capacity of the cloth to receive and retain a crease on pressing as required in tailoring.

For want of better terms, the former may be referred to as "Rough Creasing," and the latter "Sharp Creasing."

Many problems of creasing have been brought to my notice and most of these, in so far as wool materials are concerned, can be solved by proper attention being given to the yarn and cloth structure.

While empirical methods of tests, which can be used in a research laboratory can help to solve technical problems of this nature, it is highly desirable that some standard method of test should be recognised. The method of test should include a means of obtaining comparative values, otherwise visual comparison only can be made.

Mr. A. J. Borin (Manchester): The development of the analysis of cloth structure is of considerable importance as a means to the understanding of the problems of serviceability. This is particularly true with regard to the shrinkage of fabrics, wherein such analysis enables the complexities of the question to be dealt with in a logical and scientific manner. In this direction lies the means of removing the erroneous impressions that exist in the methods of describing standards of shrinkage.

The principles outlined by Dr. Peirce will undoubtedly form the future basis for the formulation of standards of performance of fabrics for shrinkage and for the other aspects of serviceability.

Mr. S. Schofield (Manchester): A question has been raised as to whether it is possible to test shrinkage to an accuracy of 1 per cent. Wash-testing to this degree of accuracy is carried out in the daily routine where Sanforizing machines are operated. The procedure is as follows:—

The samples to be tested are placed on a flat surface and marked with indelible ink, using a metal template. For easy calculation this is often 50 cm. Three markings are made both in length and width at least 1 in. away from the selvedges. The equipment usually used is a small reverse wheel, cylindrical (20 in. wheel) using a standard load of three pounds dry samples with water 50 times weight of goods, and a good grade laundry soap to give running suds. Additional pieces of cloth are added to the samples if necessary to make the standard load. The cloth should be well covered by water. The procedure then is:—

a. Place samples in wheel and start wheel.
b. Turn on water and steam.
c. Run water in to proper level—add soap.
d. Turn off steam when water boils—approx, 212°F.
e. Run wheel 40 minutes from time started.
f. Draw off water. Do not stop wheel.
g. Fill wheel to proper level with water—bring temperature to 140°F.

h. Run for five minutes.
i. Draw off water.
j. Fill to proper level—bring temperature to 140°F. Run 10 minutes.
k. Drain off water while wheel is running and run five minutes without water. Total time—60 minutes, wheel running continuously.
l. Remove samples from wheel—squeeze, do not wring. Spread out and dry on screen or ventilated surface.
m. Dampen with spray dampener—allow samples to condition five minutes.
n. Press on press machine or by hand-iron by raising and lowering iron—do not slide iron.
o. Allow samples to become cool—measure to determine change in dimensions.

This formula is approved in America by the Federal Specifications Board under their No. CCC-T-191, and is the standard method of test laid down for shrinkage in laundering of woven cotton cloth by the American Society for Testing Materials, which is approved by the American Standards Association, and is also the standard method of the American Association of Textile Chemists and Colourists developed by the latters' research committee.

Our licensees in all countries are at present following this procedure and a degree of accuracy well within the maximum tolerance of ¼-in. per yard is ensured.

A different procedure is used in the case of silk, artificial silk and other mixture fabrics.

Dr. Toy (Manchester) said he felt he should refer to one matter which had been mentioned to him during the Conference. Regret had been expressed that Dr. Peirce had been so reticent in his paper and had given them only "half a loaf". Mr. Lester had referred to the same thing and generally expressed the wish that more of the Shirley Institute's work should be published openly. He always had the greatest possible respect for what Mr. Lester said because of its intrinsic merit. But he must remind the Conference that the Shirley Institute was neither a University nor a Technical College, but a private research organisation run by the producing end of the industries it served. It was surely only reasonable that those who control its destiny should not desire to make public more than a proportion of the information gained; some people at present said, like Mr. Lester, that too little was published, whilst others said too much. Actually he felt that in the present instance it was distinctly an advantage that Dr. Peirce had been restricted in what he could say, as it enabled him to concentrate on giving a general survey of the principles involved without confusing this by going too much into details. He had kept his eyes on the "wood" as a whole and avoided the individual "trees" of detailed testing methods. What these discussions had shown was that although the mere carrying of a test might be regarded as almost a routine matter, the general problem of testing for serviceability was certainly worthy of the title of a science and the subject one needing real research.

He thought it probable that some of those present had sometimes experienced a little mental indigestion on reading Dr. Peirce's papers, but probably this had been only temporary and had given way to a real appreciation of the solid meat they contained. Personally he felt this paper was one of the best Dr. Peirce had ever written. He had been a little disquieted to hear Dr. Peirce say in his opening remarks, that for some things he would like to spend his time in the open green fields hitting golf balls. Having known his colleague intimately for six years he hesitated to emphasize his earning capacity as a professional golfer, but he thought everyone would pay him the compliment of advising him that in his own best interests, and those of the textile industries and the community at large, he should stay where he was!

Mr. Bayes (Hyde) : Though, as Dr. Toy pointed out, Dr. Peirce is restricted to general treatment of the subject, such restrictions do not necessarily apply to contributors to the discussion. It is a great pity that those who have described particular testing instruments have not given fuller descriptions of their instruments, and also very many more test results, in their written contributions.

In all textile testing, and particularly in testing for wear, and in drawing conclusions concerning general serviceability from customers' complaints, the complex variability of the material should be borne in mind and where possible the figures should be analysed statistically. The length of pieces of cloth has a standard deviation of 1 to 1½ per cent and the piece weight varies similarly. The Goodbrand strip strength varies from piece to piece in a delivery of cloth in addition to the well known variation within a piece, the within and between piece standard deviations both being round about three per cent. An apparent difference in strength between two overalls may, therefore, be due simply to this normal variation from piece to piece in a delivery, and it is very unlikely that wear tests will fail to show similar variations.

Mr. Baguley (London) : " It seemed to me a pity that a pooling of all the technical information on wearability of fabrics could not be secured. It was very obvious that on walking round the instrument exhibition that many ingenious brains had been at work designing almost identical machines. For instance, there were several workers who had adopted carborundum as the rubbing agent in abrasive wear testers. Just as many people had scrapped such machines as soon as they discovered the defects. This duplication and overlapping of research work seemed to me wasteful, and surely this was a fine opportunity for the Textile Institute to introduce a scheme whereby there would be a pooling of all technical test methods by members of the Institute."

Mr. P. Good (British Standards Institution, London) : " I greatly appreciate the invitation to be present as a guest and have enjoyed Dr. Peirce's paper and the discussion very much.

" Dr. Peirce has shown a broad outlook not always associated with research workers. It is of course the research worker's duty to create an inferiority complex in the industrialist, never to be satisfied, always seeking perfection, but in all matters including matters of test, the industry, whilst applauding and supporting that outlook, cannot afford to be restrained by it but must use the best knowledge available at the moment, even if it leaves much to be desired. This relationship Dr. Peirce successfully brought out.

" With regard to the remark that the co-ordination of tests by the engineering and allied industries owed much to the fact that the user was also a competent technician—and this certainly was the case—yet it must be borne in mind that the ultimate user even then frequently was the general public, but for reasons of safety or design there was a technical intermediary acting for the user, a condition which seemed to be arising in the textile industry through the intervention of a technical side to the distributing trade.

" When the engineering industry started to standardise methods of tests for metals they did not wait until they could accurately define the life in service of the product—the bridge, the machine, or whatever it might be. They recognised that life in service was a complex matter, dependent on factors over which the maker of the material had little control, such, for example, as painting to protect from corrosion, lubrication to diminish wear, etc. They established simple tests for such properties as tensile strength by the co-ordination of the results of such tests, which led to other tests, and it is no exaggeration to say that this work led to the development of the modern metals with their remarkable properties.

" Had the engineers not unified the elementary tests for properties and used the collective machinery of a Standards Organization, but waited to promulgate them until they knew everything about service conditions, they would still know

very little, and there could have been none of the great progressing in engineering. The steps the Textile Institute is now taking are therefore all to the good, for organised methods of test are fundamental to progress.

"Improvements in testing and methods of measurement are taking place in many industries and it is becoming evident that accuracy and uniformity of production lead to lower costs of production and the old idea that testing is costly is proving entirely false.

"The British Standards Institution in carrying out the unification of tests or publishing standards always requires that before issue the manufacturers as well as the competent users must agree to the issue and on the long view this policy has proved to be sound, although sometimes it seems a slow job to get agreement. In doing this work the British Standards Institution is well placed for collecting information over a wide range of users both here and overseas, which frequently proves of the greatest use to the research workers.

"As reference has been made in the discussion to statistical methods, it may be of interest to refer to the work done by a Committee under the Chairmanship of your Chairman to-day, Mr. Wilsdon, who skilfully guided a group of experts in the production of a treatise on 'The Application of Statistical Methods to Industrial Standardisation and Quality Control'. There is already evidence that this is proving of great value to industry, and all interested in quantity and quality production need to study the subject and apply it in their sampling and testing."

Mr. Gee (Dewsbury): As an instance of the interest which is being shown by the distributors, it might be worth while to point out that children in London, between the ages of 13 and 15, are now attending courses of instruction in textiles. A teacher engaged in the work had told me that there were 180 children in his school taking instruction in Textiles.

In the course, they were shown the differences between cloths made from wools of different qualities, and the same things with regard to cotton and silk goods. Other factors such as the "sett" of fabrics were also dealt with and the children were given information which would doubtless lead to an appreciation of yarns and fabrics, much greater than could be obtained in any other way. Many of these children would subsequently become shop-assistants, and have to sell textile goods, and the training given would lead to greater interest in textiles.

It seemed probable also that these students would eventually become the persons who would ask for various guarantees which the producers might find difficult to make. One could visualise that as this development in textile training for distributors progressed, a greater need for co-operation between the producer and the distributor would become essential, and would certainly lead to a better understanding between the two sides of the trade.

Dr. Peirce, replying to the discussion, said: "In covering the ground so widely, I have necessarily done so very lightly. Several speakers have developed important aspects more thoroughly, along lines of evident agreement, and some have taken me up on points where the sketchy treatment invited challenge. My reply must consist largely in clearing away apparent differences between views that are essentially similar. It is important to establish agreement on the purpose and principles of testing before the details are standardised, and I trust that my paper will not be regarded as an essay in logical generalisation or an intellectual exercise, but as an essentially practical discussion of our common line of action.

"Though I have tried to make the distinction clear, I must refer again to the question of imitative and characterising tests. Dr. Gibson pleads gently for the former but would not, 'make the punishment fit the crime,' and supports the thesis for tests of character with his fine old chestnut—a favourite story of my own but referring to a Borderer, not a Highlander. Professor Davis refers to the reproduction in a test of pressures observed and measured in service—by no means my idea of imitation. Mr. Lomax mentions tests of light fastness and of shrinkage, on both of which much work has been done to obtain a physical understanding of the actions and to free them from arbitrary imitative features.

"Mr. Pritchard supports, against a supposed attack of mine, a view of testing with which I am in close agreement. He gives a list of character tests specified to ensure that deliveries conform to standards established by behaviour in service. I think it possible to estimate serviceability of quite unknown fabrics by test, to an extent beyond anything claimed in his contribution. All who have been long and seriously concerned in the business of testing have probably had similar experiences, made much the same mistakes and discoveries. We will the better serve the larger and growing circle that uses test results but knows little of method, if we can clarify our own conceptions and terms. I am doing little more than urge on textile technologists the viewpoint held very definitely by engineers. They, however, have the advantage that the engineer manufacturer sells his products directly to an engineer user, who tests his materials and observes his structures objectively. Every failure is critically examined as a matter of course and the important characters determined for future demands on the manufacturer.

"In this connection, I welcome the work of Mr. Williams and support his suggestion of a pooling of knowledge by all free to give it. The large distributors and consumers are in a specially favourable position and the collection of their data would assist producers to meet their needs. It would be useful, to supplement the figures he gives, to have frequency curves of values obtained by random selection of new materials.

"I would subscribe to Professor Morton's remarks almost in their entirety and his approach to the problem is very similar to that adopted at the Shirley Institute. Had it been my purpose to describe our own observations in detail, his description might have been followed quite closely, and it is illustrated by the photo-micrographs reproduced in our exhibit. The low structural coherency measured by brushing with card fillet is only one character involved in service abrasion ; the abrasion of the fibre material in a firm structure is another, best studied by cloth abrasion. In both methods, we agree that the work done by friction is a better basis of expression than arbitrary mechanical measures of action, such as number of rubs. A smooth mineral abrasive might abrade by surface traction and correlate well with abrasion by cloth or in service. Even a cutting abrasive measures something which, if understood, might be interpreted intelligently. Having used such myself, I do not condemn trying them, nor using them for what they prove to be worth.

"The contribution of Mr. Mann brings out a point very cursorily touched on in my paper but to which a large portion of our work on abrasion is devoted—the necessity to vary all the arbitrary conditions of a test, abrasive, pressure, speed, orientation, tests of damage, etc., to see what influence arbitrary choice has on the ranking of fabrics. In comparing the results of different tests, including service, the significance of any correlation depends on the range of samples compared. A set of samples of the same cotton fabric tendered chemically to different degrees will be ranked similarly by almost any destructive test—but the character that decides the rank is measured better by fluidity than by any tensile or abrasive test. A rayon fabric ' fibres ' less easily than a cotton one, so Mr. Lester finds it survives longer in the card fillet test ; but the fibre is less tough, so it fails more quickly against wool. An abrasion test is not justified by the mere fact of correlation, even with service, unless it measures some character not determined by a simpler test.

"In reply to Mr. Harwood, I must plead the unavoidable sketchiness of my detail. The emery test and shrinkage were chosen as simple examples to illustrate certain points. I could not with the whole space deal adequately with shrinkage in all its aspects. My remarks were meant primarily for cotton and apply more generally to the many fibres on which the structural effects of swelling are the predominant cause of shrinkage. In wool, the tendency to felt and the firm retention of extremely slack woven structure introduce quite different and very complex characters that need separate treatment from swelling shrinkage. No test for the ' fully shrunk ' state can have definite meaning when applied to a felting material."

Yorkshire Section.

TEXTILES ON TEST IN THE CUSTOMERS' INTERESTS

By J. G. WILLIAMS, B.Sc., A.I.C., A.T.I.
(Merchandise Research Laboratory, Selfridges, London).

Abstract of a talk to the Yorkshire Section of the Textile Institute at the Midland Hotel, Bradford, on March 11th, 1937.

Mr. Williams stated that the work of the laboratory in an organisation such as that to which he belonged was necessarily very varied indeed. As he was speaking to people, the majority of whom were engaged in the production of textiles, he proposed to confine his remarks to the testing of textile materials in connection with their distribution. Though the title of his lecture was " Textiles on test in the customers' interest," he pointed out that the interest of the large retailers was inseparably bound up with that of the customer; for only by testing could quality be measured beforehand and if the customers felt that they were not getting good value for money they did not continue their patronage.

Towards the end of 1933, a committee of the Incorporated Association of Retail Distributors met with the object of setting up " Standards of Retail Practice." For a number of years there had been a steady decline in the quality of many of the textile materials offered for sale, the causes of which it was not the present purpose to trace. In March, 1935, the Retail Trading-Standards Association was formed by distributors prepared to accept and endorse these standards. Obviously the first thing for any retailer to do was to ensure, if possible, that goods offered for sale were correctly described. This naturally necessitated the framing of definitions that would command general acceptance, which proved to be a problem of considerable difficulty, capable of solution only in the laboratory. In its enthusiasm for this scheme, one large firm offered a reward of £10 to the first person indicating falsity in the advertising of its merchandise.

Mr. Williams explained that he did not propose to deal with methods of testing or the interpretation of the results except in broad outline. He showed a cinematograph film taken in the laboratory which actually gave a better idea of the work of the laboratory than could be done in a long talk. In large retail stores, it was obviously impossible to test representative samples of every one of the lines sold. If all the lines sold were tested, the tests would have to be made in the establishments in which the goods were produced. Consequently, many compromises were necessary. In the distributing group served by Mr. Williams' laboratory, the managers of departments were invited at all times to send for testing and examination samples of the articles they were selling, if they wished to have further information about them. If buyers were in doubt about the lines offered to them, they could send samples to the laboratory for investigation. From time to time, goods were offered to stores at specially attractive prices. The offers might be genuine and might be made because the vendor was in urgent need of money, because a contract had fallen through, or because stocks had to be cleared to make room for new productions. If, on the contrary, the prices were low because the goods were defective, well-organised testing should expose the faults. An example was provided by an offer of 50,000 poplin shirts, the material for which had been excessively tensioned in finishing. On laundering, the shrinkage was so great that sleeves became too short and neck-bands too tight, making the goods hopelessly unsatisfactory in service.

To some classes of merchandise, the possible application of tests may be far more complete than to others. Cotton bed sheets afford an excellent example. When the sales departments agree upon the retail selling price, the wholesale price is automatically settled and contractors can be invited to submit samples, which are duly submitted to test. The managers of the departments concerned

consider the results of the tests together with appearance, handle and other relevant factors and the contract is placed to cover supplies for twelve months. At intervals, samples from other mauufacturers attracted by the possibility of securing a large contract are received and tested, so that when the next contract is due to be placed a better article may be available at the established price. Wholesale buying on these lines has now been applied to an extensive range of standard goods sold throughout a group of associated stores.

When every possible effort has been made, it is, as already stated. impossible for the retailer to test every line of merchandise sold in the modern store. Some customers are bound to be dissatisfied with their purchases and the distributor sincerely hopes to receive their complaints. Unless the complaint is made, there is no possibility of affording satisfaction. The trouble may be due to defects in the materials or garments, or it may have arisen through incorrect treatment subsequent to purchase. In the former case, the distributor will take up the question with the manufacturer or the garment-maker, and in the latter will endeavour to inform the customer for future guidance. Defective lines must damage the retailers' goodwill, and it is but fair that customers should duly make the complaint. In general the policy governing the treatment of complaints is one of generosity because, in the long run, generous treatment proves to be a good investment.

From the point of view of the laboratory workers, complaints are of the utmost value. The scientists' keenest regret is that of the people who have made unsatisfactory purchases, so very few will take the trouble to complain. The laboratory attached to the retail store has little to do directly with fundamental scientific research. The tenacity of a fibre in grams per denier is undoubtedly of great importance, but many other factors of at least equal weight enter into the complex question as to whether a garment in which that fibre is incorporated will give satisfaction or not. The investigation of complaints, metaphorically provides the bricks which are the units in the structure of information which the retailers' laboratories build up. The tests made in such laboratories can rarely be other than comparative—the tests on complaints indicating the limits of test results in which poor serviceability can be expected. If tests on a new line show that the strength of the fabric is of the same order as that normally found in goods returned as defective, the laboratory's advice to the buyer would be to refrain from purchasing.

If it is desired to prove the need for the testing of merchandise in the customers' interest, it is necessary only to consider the growth of the work in a testing laboratory attached to a retail stores. Ten years ago, 450 samples were examined in the twelve months ; last year the total was 1600. From 80 per cent. to 85 per cent. of the reports issued dealt with textiles. Of the investigations of textile materials about 40 per cent. arose in connection with wholesale buying and selling, and 50 per cent. to 55 per cent. from complaints. From an analysis of 750 complaints, it was found that 40 per cent. were due to defective materials, 40 per cent. to incorrect treatment after purchase, and in the remaining 20 per cent. both factors operated. As the number of complaints investigated increases, it becomes possible to specify more and more accurately the limiting values below which the strength should not fall if satisfactory wear is to be guaranteed.

It is possible to illustrate briefly the great variety of tests necessary in a merchandise laboratory. Linen sheets are robust fabrics easily made with a comfortable margin of strength. Fine gauge silk stockings, on the contrary, are so delicate as to require the gentlest handling in wear and washing. Fortunately, the public soon learns to treat the various fabrics and garments as they should be treated. The strength test, however, is by no means the most important. Garments may become completely unserviceable long before they are worn out. The dyestuffs employed may not be sufficiently fast to light

to stand reasonable exposure without marked fading. Fortunately this is one of the directions in which tests, prior to sale, can be made fairly satisfactorily. Garments may shrink to such an extent that they become too small after a few launderings. This may be due, as in the case of wool, to an inherent property of the fibre from which the material is made. After the application of the various treatments to counteract this felting tendency of wool, tests can easily be made to see if the material is reasonably unshrinkable. Of perhaps greater importance, is the shrinking of cotton goods, which is really due to recovery from excessive tensioning during manufacture. The importance of this may be gauged by the great demand for garments made from pre-shrunk, or more correctly, detensioned, materials. The results accumulated in the course of routine testing permit the determination of permissible degrees of shrinking on laundering.

Tests of the nature of those outlined above lead to at least one very useful result. They provide the real information in the pamphlets which frequently accompany garments of certain makes, giving advice regarding the treatment of fabrics and garments. If the risks entailed in the use of various materials, such as in the ironing of acetate rayon, are known, they are easily avoided.

From the strictly scientific point of view, the results of these investigations are scrappy, and the reply to such true criticism is that it is inevitable. The merchandise laboratory pursues entirely different aims from those of the research laboratory proper, but its work is resulting in the amassing of information of value in the determination of serviceability. It will continue to grow in value and usefulness.

Correspondence

"MODERN DRAFTING IN COTTON SPINNING."

BY J. NOGUERA.

To the Editor.

Sir,

May I be permitted to answer one or two points contained in the review of "Modern Drafting in Cotton Spinning," which appeared in your June issue ?

When dealing with the "ordinary" mill practice, I mention in my book the damage caused to the regularity of the strand by the drafting at each subsequent process of speed frame, and how regularity is more or less successfully kept up by means of doublings at each machine. I point out that each doubling, whilst by itself improving the regularity, is nevertheless a potential cause of irregularity in that it makes more drafting—more irregularizing action—necessary. Thus on page 21 :—

"*These doublings improve or, rather* (owing to subsequent bad drafting, etc.), *maintain somewhat the regularity in weight per unit length,* although they have the great disadvantage of making further calls on the drafting mechanisms which have to draft twice as much for every time two ends have been doubled. *In this respect the doublings are often a real—though quite indirect—cause of unevenness in the final yarn.*"

Mr. H.B. quotes the portions shown above in italics (although his review states "irregularity" where it should be "regularity") and states that they are contradictory. I have re-read the passage complained of but cannot find where the contradiction is.

I respectfully believe my reviewer is again wrong about my calculations of the chances of variations arising in doubling and drawing. The first example mentioned in the book considers the possible combinations of two slivers, each composed of six imaginary portions (longitudinally), four of these portions

being of the correct weight, whilst one is 12.5 per cent. too heavy and the other 12.5 per cent. too light. I give the possible combinations thus :

18 chances of 0 per cent. variation
16 chances of $\pm$ 6.25 per cent. variation
2 chances of $\pm$ 12.5 per cent. variation

$6^2 = 36$

This can easily be analysed as follows :—

		Sliver B					
		100	100	100	100	112·5	87·5
Sliver A	100	200	200	200	200	212·5	187·5
	100	200	200	200	200	212·5	187·5
	100	200	200	200	200	212·5	187·5
	100	200	200	200	200	212·5	187·5
	112·5	212·5	212·5	212·5	212·5	225	200
	87·5	187·5	187·5	187·5	187·5	200	175

Yet Mr. H.B. says the combinations are :

18 of 0 per cent. variation
16 between $\pm$ 12.5 per cent. variation
2 between $\pm$ 25 per cent. variation.

No doubt he has become temporarily confused in thinking that the addition of the two 12.5 per cent. variations will make one 25 per cent. variation.

J. NOGUERA.

Reviews

An Investigation into the Sickness Experience of London Transport Workers, with special reference to Digestive Disturbances. By A. Bradford Hill. Report No. 79, issued by the Medical Research Council. (His Majesty's Stationery Office. Price, 6d. net, postage extra.)

After reading this report it is impossible to do otherwise than congratulate the author. Statistical investigations of this nature are always difficult and generally yield results capable of as many interpretations as there are interpreters. Dr. A. Bradford Hill has, in this case, been dealing with singularly difficult material. The fact that his findings roughly confirm the belief held by the omnibus men themselves that gastric trouble is unduly common among them can be easily over-emphasized.

The only available standard of comparison free from fatal objection appears to have been afforded by the information concerning the tramway workers. Imperfect and incomplete records caused the enquiry to be limited to the short period of two years. The more extensive occurrence of gastric disorder among omnibus workers in comparison with tramway employees is certainly too great to be insignificant. The results of the work would appear to call for further extensive observation, with a view to the determination of the causes of the undue incidence of gastric trouble. Constructive suggestions might then be possible.

T.

Additions to the Library.

General Wage Census—Part 1—Perennial Factories. Third Report. Labour Office, Government of Bombay. (Government Central Press, Bombay. 1937. Price, Annas 12 or 1/3.)

Annual Report of the Department of Agriculture in the Bombay Presidency, 1935-1936. (Government Central Press, Bombay. 1937. Price, Annas 10 or 1/1.)

Cotton Year Book, 1937. (Published by the "Textile Mercury," 41 Spring Gardens, Manchester, 2.)

Wool Year Book, 1937. (Published by the "Textile Mercury," 41 Spring Gardens, Manchester, 2.)

Trade Mark and Monogram Suggestions. Samuel Welo. (Sir Isaac Pitman & Sons, Ltd., London. 1937. Price, 10/6.)

75 Jahre Kleinwefers. (1937. Kleinwefers, Krefeld.)

THE JOURNAL OF THE
TEXTILE INSTITUTE

Vol. XXVIII AUGUST 1937 No. 8

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

Testimonial to Dr. F. W. Eurich.

At the July meeting of the Institute Council, reference was made to the retirement of Dr. F. W. Eurich, M.D., Edin., formerly Bacteriologist to the Anthrax Investigation Board for Bradford and District. Attention was drawn to the pioneer work Dr. Eurich had performed in connection with investigation into the then alarmingly-frequent woolsorters' disease. The present-day position of almost complete freedom from this menace to the health and lives of workers in the wool industry can be attributed in the main to his work, and in recognition thereof it was stated that a testimonial was being raised not only by the medical profession, but at the instigation of the British Wool Federation and the Chamber of Commerce, Bradford. The Council, feeling that members of the Institute might wish to be associated with this testimonial, instructed that reference be made to the matter in the next issue of the *Journal*. It is also to be stated that contributions to the Testimonial Fund may be addressed to the Hon. Treasurer at Institute Headquarters.

Sectional Meetings during the Winter Session.

Section Committees are actively engaged in the arrangement of lectures and visits for the forthcoming winter session. Interest seems to be at a higher pitch than for some years past, and the Midlands Section programme has already been printed. The first event is a visit to the works of Messrs. J. & T. Tinkers, Ltd., Holmfirth, on 29th September. The Section dinner is fixed for Friday, 10th December, and the programme also includes lectures by Dr. J. B. Speakman, Dr. E. R. Trotman, and Mr. J. K. Ebblewhite. Other Section plans are known to be well advanced, and full programmes will be issued at an early date. The Institute's plans in connection with its Standardisation Scheme, of which particulars will be published in the September issue, are arousing much interest, and quite a dozen requests for lectures on the subject have been received. Those arranged already include a meeting at Bradford of the Textile Society to which Yorkshire Section members and members of the Society of Dyers and Colourists will be invited; a meeting at the Stroud and District Technical College; a meeting of the Lancashire Section conjointly with the Oldham Technical Association; and a meeting in Belfast of the Irish Section. At this latter meeting it is hoped to be able to hand to Mr. W. H. Webb, Chairman of the Section, the Institute Medal he was unable to receive personally at Southport. The first meeting of the Lancashire Section will be a lecture by Mr. N. C. Marples, of Henry Wiggin & Company Ltd., on Wednesday, 22nd September, at the Institute. Mr. Marples will speak on "Some High Nickel Alloys—their properties and uses in Textile Wet Processing."

BIOLOGICAL STUDIES ON SOUTH AFRICAN MERINO WOOL PRODUCTION*

By VICTOR BOSMAN, M.Sc., D.Sc.
Onderstepoort Research Laboratories, Pretoria, South Africa

INTRODUCTION

Merino Wool Production is the major pastoral industry of the Union and in export value the wool clip is second only to gold. Statistics show that the quantity of raw wool exported has trebled itself during the past twenty-five years, and in the 1934-35 season the total production was over two hundred million pounds in the grease.

In South Africa, the merino sheep is farmed under very varying conditions of soil and pasturage and under differing climatic influences. These, associated with problems of breeding and selection, tend to complicate any studies on the fleece. Many factors controlling wool production and the extent to which these factors influence production, are still obscure and need investigation. The subject has received the attention of several investigators who, however, have mainly dealt with breeds of sheep other than the merino. The present investigations are confined to the South African merino, and in this thesis the problems have been studied from biological aspects and an attempt has been made to analyse some of the factors which control wool production.

In the first part, methods for determining the fleece characteristics are described. The second part deals with production and describes the interdependence of the fleece characteristics, and the weight of wool produced. It also discusses the stress that fleece characteristics deserve in sheep selection. The second part of section II describes experiments that deal with nutritional and other environmental influences. The third section describes the fibre fineness of South African wool, whilst in the fourth section the fleece analyses of merino stud sheep are discussed from a statistical standpoint. At the end of the thesis a general discussion is given. It has, however, been necessary to include a certain amount of discussion and conclusions within the sections themselves.

I. METHODS FOR DETERMINING MERINO FLEECE CHARACTERISTICS

In South Africa, the practical sheepman takes into account individual fleece attributes in sheep selection and wool classing. Among the fleece attributes considered are length, fineness, fleece density, crimping, fleece weight, softness of handle, colour and uniformity.

A chronological review of different laboratory methods for analysing fleece characteristics is given by Kronacher and Lodeman (1929), and Barker (1929; 1931), and numerous workers are quoted. In discussing wool measurement technique and the nutritional and genetic aspects of wool production, Burns (1933), emphasises the importance of suitable methods for analysing the fleece characteristics of the merino, and discusses some methods in use. In the present study, several laboratory methods for analysing the fleece of the merino were put into practice, with a view to adopting those most suited for routine fleece analyses.

A. FIBRE FINENESS

Merino wool is characterised by fibre fineness. (Fibre fineness is here used in the technical sense denoting fibre thickness or fibre width.) In "A Survey of the World's Wool," published by the Empire Marketing Board (1932), the report differentiates three main types, merino, crossbred and carpet, the basic

* Thesis approved for the degree of Doctor of Science by the University of South Africa.

distinction depending on fibre fineness. It was also shown that merino wool has the largest range of quality numbers, with limits from 60's to 100's, that crossbreds range from 36's to 58's, and carpet wools from 22's to 34's.

Since fibre fineness is recognised as a most important attribute, its determination has received the attention of many research workers and several workers have used fibre fineness for classifying merino wool into quality numbers, viz.: Duerden (1929) ; Winson (1931) ; Plail (1930) ; Dantzer et Roerich (1929) ; and others. In his work on " Wool Quality," Barker (1931) gives a comprehensive review of the publications on this topic. Different authors have used different systems for expressing fibre fineness, and whilst some have adopted fibre thickness or fibre width, others have used methods based on gravimetric analysis or on the diffraction of light.

For the present investigation several methods were tried out in order to find the most suitable one for routine fleece analyses where large numbers of measurements are necessary. These methods included the weight-length method, Roberts (1927) ; the diffraction method, Ewles (1928) ; Duerden (1929) ; the micrometer method, Burns and Koehler (1925), and the cross-sectional area method, Barker and Burgess (1928). The microscope method and adaptations of this have been described by several workers, e.g., Henseler (1926) ; Barker and March (1928) ; Doehner (1929) ; Duerden (1929) ; Rausch (1934) ; Gavazzi (1934). Several authors have compared the advantages and disadvantages of the various methods for estimating fibre fineness, e.g., Roberts (1930) ; Barker (1931) ; Rausch (1934 ; 1935) ; Doehner (1935), and others. In September, 1935, the International Wool Congress, with representatives from nine countries, appointed a select committee to discuss the question of standard methods for the measurement of the fineness of wool. It was agreed that standard methods for the measurement of wool fineness are essential and that the results of further investigation from the laboratories of the countries represented, are to be reported to the Congress to be held in Warsaw in 1936.

For routine fleece analyses on the South African merino, the camera method of measurement and sampling, described by Duerden (1929), has been adopted. The advantages of the camera method are mainly that the fibre distribution and measure of variability within the sample are obtained, and in this respect the method differs from the weight-length or diffraction methods. The degree of variability is of significance from the producer's point of view, and the camera method is therefore preferred. In addition, it is a quick and ready method and a thorough sampling of any wool sample is possible. As pointed out by Duerden (1929), repeat tests of the same sample, and a series of samples analysed by both methods, have shown great consistency. The assertion that the wool fibre is not perfectly circular, Barker (1931) ; Winson (1929), and others, and that the microscope measurement gives rise to error, has been considered, and advocates of the microscope method, Rausch (1935) ; v.Wyk (1935), and Doehner (1935), have pointed out that when large numbers of measurements are made, irregularities, due to the differences between the major and minor axes of the elipses, are evened up, and the means obtained by the miscroscope are sufficiently accurate.

B. FLEECE DENSITY

The term " density " is used by the practical sheep judge to denote compactness in a fleece. In discussing the " Interpretation of the Merino Score Card in South Africa," Rose (1930) refers to density as meaning " the close proximity of fibre growth on a given surface of skin."

Several research workers have attempted a more precise definition, and Duerden and Botha (1930), suggest either " the volume of wool material of a certain length " or " the weight of wool material of a certain length grown on a constant skin area." Burns and Miller (1931), in their work on " Sampling instruments to determine fleece density in sheep," refer to density as meaning

" the total amount of wool fibre growing on a definite unit area of skin, usually on the living animal."

In general, workers are agreed that the expression for fleece density is based on the number of fibres growing per unit area of skin and some use this factor only, e.g., Hultz and Paschal (1930), Burns (1926 ; 1933). It is, however, contended that in estimating fleece density, the number of fibres per unit area must be associated with fibre fineness. Whichever system for expression is used, the number of fibres growing per unit area is the basis, and the estimation of this is essential. The determination of the other factor of fibre fineness has already been referred to.

Two methods for determining the number of fibres growing per unit area of skin were investigated, and a comparison was made of their relative merits for routine analyses of merino fleeces.

Sampling. Sampling instruments used to delimit unit areas of skin on the sheep have been reviewed by Burns and Miller (1931). Of these, the more recently developed instruments, the Idaho wool caliper, Nordby (1928), the Duerden wool caliper, Duerden (1929), the Wyedesa and the Wyedena calipers Burns and Miller (1931), as well as the porcupine quill methods, were given a trial and it was found that for the dense merino sheep, the Wyedena wool caliper was most suited and was adopted for routine density determinations in the present work. The caliper delimits four square centimetres of skin area and the wool is clipped from the area with fine nail scissors. Repeat tests on the same region of the animal have shown great consistency.

In genetic studies, different regions of the sheep must be sampled in order to take into account the variability in density, Botha (1930). A similar system of regional sampling was used by Hultz and Paschal (1930), and by Burns (1933).

Estimating the number of Fibres. To estimate the number of fibres in a sample, most workers have adopted the method of counting a portion of the fibres, and then by comparing the weight of the portion with that of the large sample, forming an estimate of the number. Burns (1933) ; Duerden and Botha (1930) ; Hultz and Paschal (1930) ; Bosman and Maré (1933), have used this method.

In the present study an account of the weight-volume method is given and a comparison is made between results obtained by it and by the counting method.

A series of samples obtained by means of the Wyedena fleece caliper from merino stud ewes was analysed by both the counting-method and the weight-volume method. Each sample was cleansed of wool grease and other impurities by the benzene-saponin method described by Miller and Bryant (1932). During scouring, care was taken to keep the fibres undisturbed in the sample so as to avoid any matting. Each sample was handled by means of forceps and after drying, five hundred fibres were counted as a random selection from the skin end of the staple. The bundle of counted fibres and the large sample were allowed to stand in the balance case before weighing so that both were weighed under similar conditions. By simple proportion the number of fibres was then calculated.

The alternate method, by weight-volume, was used on the same samples. This method takes into account the dry weight of the sample, the volume of the wool (from a knowledge of the length of the fibres and their fineness) and the specific gravity of wool. The number of fibres is calculated by the formula:

$$N = V/S.A.L.$$

where N is the number of fibres ; S, the specific gravity of wool, adopted as a constant 1·30, King (1926), Speakman, Stott and Chang (1933) ; A, the mean cross-sectional area of the fibres, and L, their mean straight length.

The dry weight of wool was obtained by the method of Barritt and King (1926). A current of dry air maintained at 104°C was passed through the wool sample which was contained in a specially designed regain bottle. The mean

cross-sectional area of the fibres was calculated from the mean fibre fineness measured by the micro-camera method. The straight length was obtained by measuring fifty fibres at random from each sample according to the method used by Burns (1929).

The two methods were tested on twenty-six merino stud ewes and the results are summarised in table 1. A close agreement between the two is shown. The number of fibres growing per square centimetre of skin and per square inch are given in each case. In the last two columns of the table are given the mean fibre fineness and the fleece density in terms of percentage skin area occupied by wool fibres.

The weight-volume method for estimating the number of fibres per unit area gives results that agree closely with those obtained by the counting-weighing method. The author found the former preferable to the latter and has adopted it for routine analyses and density determinations in merino genetic studies. The weight-volume method has its advantages in the fact that it eliminates the laborious counting of 500 fibres from each sample. The factors necessary in its calculations are dry weight of the sample, straight fibre length and mean fibre fineness. The latter two are determined in the ordinary course of fleece analyses in genetic studies and the only additional determination necessary is the dry weight, thus simplifying the method.

Separate complete tests have shown that the weight-volume method is quicker than the 500 counting method when large numbers of routine samples are analysed. With a convenient heating apparatus that holds a number of regain bottles, the determination is greatly facilitated. Furthermore, in wool research laboratories which have a constant humidity chamber for conditioning the samples, the heating stage can be dispensed with and the dry weight can be determined from humidity charts after the samples have been conditioned.

Table I

Comparison of Results Obtained by the Counting Method and by the Weight Volume Method in Fleece Density Determinations

Sample	By the Method of Counting 500 fibres.		By the weight-volume method.		Mean fibre thickness in μ.	Fleece Density as percentage skin area.
	No. of fibres per sq. cm.	No. of fibres per sq. inch	No. of fibres per sq. cm.	No. of fibres per sq. inch		
1	6,500	41,930	6,475	41,790	19·09	1·85
3	9.295	59,970	9.257	59,730	19·05	2·64
4	8,615	55,580	8,607	55,520	19·64	2·61
5	8,990	58.000	8,985	57,970	20·60	2·99
6	8,292	53,500	8,115	52,350	17·46	1·94
7	6,905	44,550	6,992	45,110	20·60	2·33
8	6,110	39,420	6,087	39,270	20·37	1·98
9	6,430	41,480	6,470	41,740	19·29	1·89
10	9,000	58,060	9,150	59,030	20·76	3·10
11	8,327	53,730	8,300	53,550	20·62	2·77
12	5,760	37,160	5,930	38,260	21·48	2·15
13	6,450	41,610	6,465	41,710	18·95	1·82
14	7,435	47,970	7,392	47,690	20·73	2·49
15	6,025	38,730	6,032	38,920	21·67	2·22
16	5,552	35,820	5,550	35,840	20·91	1·91
17	5,750	37,100	5,815	37,516	22·30	2·27
19	7,362	47,500	7,315	47,190	20·26	2·36
20	6,850	44,190	6,820	44,000	17·09	1·66
22	10.607	68,440	10.530	67,940	16·93	2·37
23	6,340	40,900	6,457	41,660	21·85	2·42
24	7,015	45,260	7,107	45,850	20·73	2·40
25	9,370	60,450	9,300	60,000	20.62	3·10
26	5,652	36,470	5,637	36,370	19·27	1·64
27	5,907	38,110	5,932	38,270	21·25	2·10
29	7,000	45,160	7,070	45,610	18·03	1·80
30	6,070	39,160	6,100	39,350	22·57	2·44

The number of fibres per square centimetre as well as per square inch is given, as both systems are employed by research workers.

The fibre fineness and the fleece density expressed as percentage skin area occupied by wool fibres are given. It is shown that the number of fibres alone does not express fleece density. For example, sample No. 22 with 10,530 fibres per square centimetre and a mean fibre fineness of 16·93μ is less dense, with 2·37 per cent. fleece density, than sample No. 25 which has 9,300 fibres per square centimetre, a fibre fineness of 20·62μ and a fleece density of 3·10 per cent.

The relationship between skin area occupied by wool fibres, the number of fibres per unit area of skin and the fineness of the fibres, is demonstrated graphically in Fig. I. A few examples obtained from the graph are summarised in Table II.

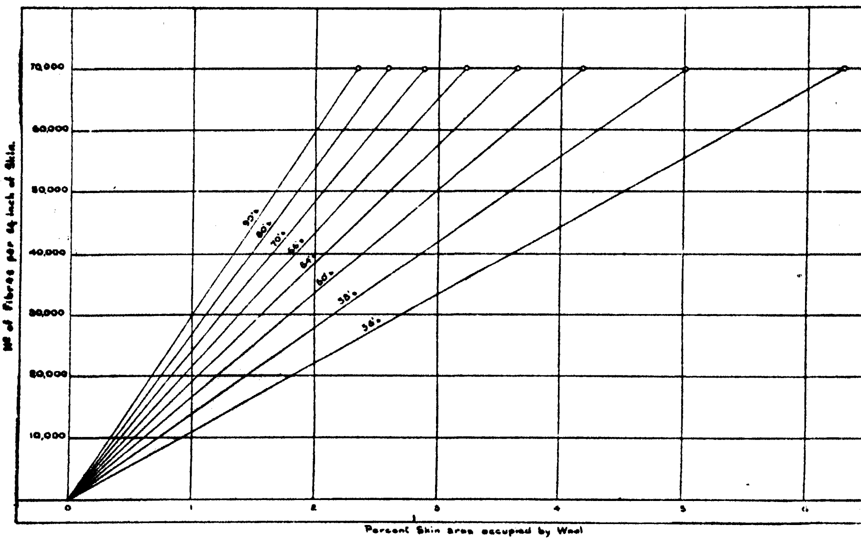


Fig. 1. Graph showing the relationship between the number of fibres growing per square inch of skin, quality number and the per cent. skin area occupied by wool fibre.

Table II

The Relationship between Skin Area occupied by Wool Fibres, the Number of Fibres per Unit Area of Skin and the Fineness of the Fibres

Number of fibres per square inch of skin.	Quality Number.	Percentage Skin Area occupied by wool or fleece density.
25,000	60's	1·50
25,000	64's	1·30
25,000	70's	1·05
40,000	60's	2·40
40,000	64's	2·10
40,000	70's	1·65

In Table II it is demonstrated that the number of fibres growing per square inch of skin is not the only factor that determines the fleece density. Much depends on the quality number or fibre fineness of the sample. Sheep with 25,000 fibres per square inch can vary in fleece density from 1·05 to 1·50 per cent. depending on whether the quality number is a 70's or a 60's. The fleece density of a sheep with 40,000 fibres per square inch can vary from 1·65 to 2·40 per cent. according to whether the quality number is 70's or 60's.

Density determinations are becoming increasingly important in fleece analyses since they play a significant role in wool production.

C. FIBRE LENGTH

The fibre length of merino wool is dependent on the rate of growth of wool, Fraser (1931) ; Burns (1931); Duerden and Maré (1931), and is influenced by genetic as well as nutritional factors (Bauer and Kronacher (1919) ; Ewart (1919) ; Davenport and Ritzman (1926) ; Elpatjevsky (1929) ; Wilson (1927) ; Hardy and Tennyson (1926)). It can be measured either as mean straight length or as staple length. The former is the true length while the latter is an apparent measurement and is dependent on the type of crimping (Duerden and Bosman (1931)). Both methods of expression are used in the study. Several authors

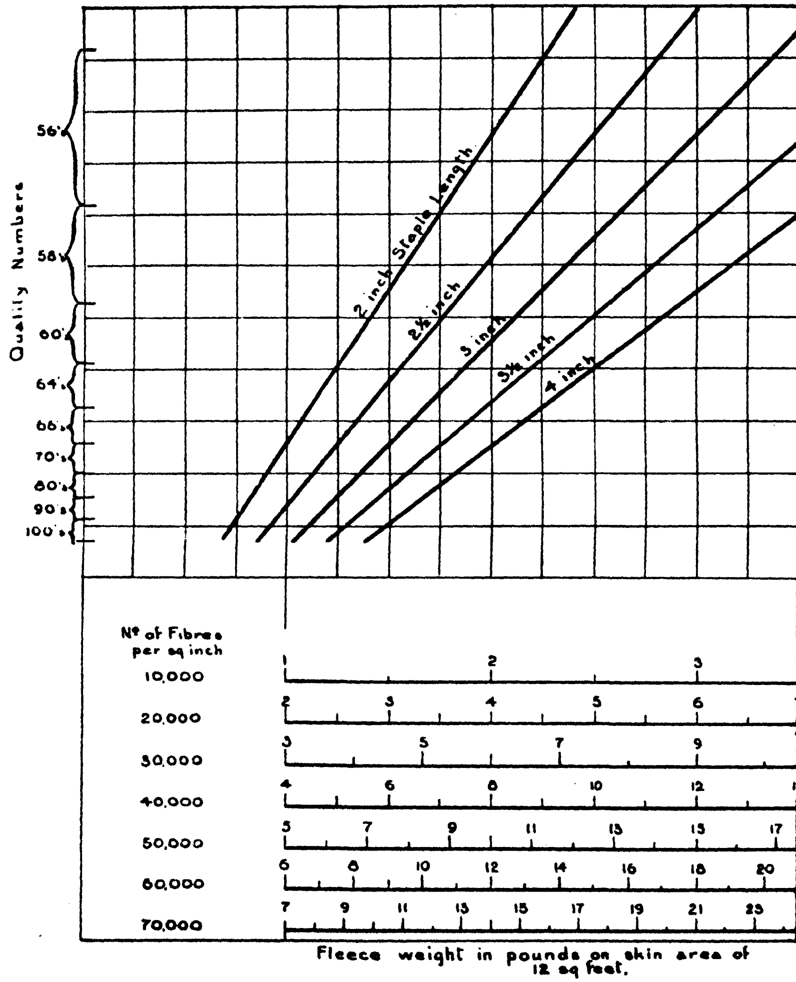


Fig. 2. Graph showing relationship between quality number, staple length, number of fibres growing per square inch of skin and scoured fleece weights.

have discussed methods of measuring length, e.g., Duerden (1929) ; Burns (1929) ; Sever (1932), and the instrument devised by the latter was tried for routine analysis, but the direct method, using a pair of wool forceps against a graduated scale, was found more suitable.

II. MERINO WOOL PRODUCTION

The South African Merino wool clip, from an adult sheep population of thirty millions, with an average production of seven pounds of greasy wool per sheep, includes that from the general flock merinos as well as from the more improved stud animals.

Merino stud sheep produce appreciably more fleece weight than the seven pounds average, and it is not uncommon to find stud rams giving up to thirty pounds of greasy wool with ten to twelve pounds of scoured wool. This higher production of stud animals has been attained by rigid selection in breeding practice. In addition to sheep selection in wool production, the sheepman must take into account nutritional and other environmental factors.

A. THE INTERDEPENDENCE OF FLEECE CHARACTERISTICS IN WOOL PRODUCTION

The merino farmer practises selection among his sheep and bases his observations of the fleece characteristics on empirical methods of hand and eye. These methods, however, do not permit of numerical comparisons, and, being on a relative basis, are often liable to error. Where arithmetic values for the fleece characteristics have been worked out, it is shown that valuable comparisons can be made. The characteristics of the fleece influence wool production directly and the relative importance of the fleece attributes in relation to production is established.

In experimental work, the usual method employed for determining fleece weights consists of shearing, scouring, and then weighing the fleece, Wilson (1928) ; Botha (28). In the present study a method is outlined whereby scoured fleece weights can be determined on the live sheep. Advantages of this method lie in the fact that a study can be made of the rôle that each fleece characteristic plays in wool production, and the weight of clean wool that is produced by a merino sheep can be estimated without shearing the animal.

(*a*) *Attributes that Influence Fleece Weights.* The weights of merino fleeces, which for strict comparisons must necessarily be on a scoured basis (Spencer, Hardy and Brandon (1928 ; Bosman (1931)) are influenced by such factors as, size of skin area of the sheep, mean fibre fineness, fibre length and number of fibres grown per unit area of skin. Fleece weight can be theoretically calculated from the following:

$$W = L \times A \times d \times n \times S$$

where W is fleece weight, L, fibre length, A, cross-sectional area of the fibres, d, specific gravity of wool (taken throughout as 1·3 (King (1926)), n, number of fibres grown per unit area of skin and S, total skin area of the animal.

Calculations of fleece weights obtained by this method are given in Table III and Figure 2. The values for quality numbers based on fibre fineness are represented on the ordinate of the graph as cross-sectional areas of the fibres. They are calculated with a fibre contour of 1·00 (Barker and Burgess (1928)), from fibre fineness standards of South African merino greasy wool (Duerden (1929); Duerden and Bosman (1929)). On the abscissa of Figure 2 are given the fleece weights in pounds. The number of fibres per unit area, ranging from 10,000 to 70,000 per sq. inch, is also given to cover the variation that can occur in merino sheep in South Africa. The diagonal straight lines represent the different values for staple lengths, which have a crimp ratio of 1·4 (Duerden and Bosman (1931)). The staple lengths of 2, 2½, 3, 3½, and 4 inches respectively, were chosen to harmonise with the units used by the practical sheepman. The scoured dry weights are calculated on a skin area of twelve square feet as this is found to be an approximate figure for a well grown sheep in South Africa.

(*b*) *The Merino Slide Rule.* From Table III and Figure 2 the weights of fleeces can be obtained for differing values of fibre fineness, length and number of fibres per square inch. These data were utilised to construct the merino slide rule (Figure 3) which can conveniently be used for determining the fleece weights for any combination of fleece characteristics.

Quality numbers, based on fibre fineness, and also fleece weights for differing numbers of fibres per unit area, are given as fixed points. The sliding rule containing the values for staple lengths, is moved so that the quality number of

Table III
The Values for Fibre Fineness, Staple Length, Number of Fibres growing per Square Inch of Skin and the Scoured Fleece Weights

Qual. No.	Fibre Thick-ness in μ.	Staple length (inches) (with crimp ratio 1·4)	Weight of fleece for the different number of fibres per square inch. Calculated on a skin area of 12 sq. feet. (in pounds).						
			10,000	20,000	30,000	40,000	50,000	60,000	70,000
100's	15·80	2	0·69	1·38	2·07	2·76	3·45	4·14	4·84
		2½	0·86	1·73	2·59	3·45	4·32	5·18	6·05
		3	1·03	2·07	3·11	4·14	5·18	6·22	7·25
		3½	1·20	2·42	3·63	4·84	6·05	7·25	8·46
		4	1·38	2·76	4·14	5·53	6·91	8·29	9·67
90's	16·60	2	0·76	1·53	2·29	3·05	3·81	4·58	5·34
		2½	0·95	1·91	2·86	3·81	4·77	5·72	6·68
		3	1·14	2·29	3·43	4·58	5·72	6·89	8·01
		3½	1·33	2·67	4·00	5·34	6·68	8·01	9·35
		4	1·52	3·05	4·58	6·10	7·63	9·16	10·68
80's	17·45	2	0·84	1·68	2·53	3·37	4·21	5·05	5·90
		2½	1·05	2·10	3·16	4·21	5·27	6·32	7·37
		3	1·26	2·53	3·79	5·06	6·32	7·58	8·85
		3½	1·47	2·95	4·42	5·90	7·37	8·85	10·32
		4	1·68	3·37	5·06	6·74	8·43	10·11	11·80
70's	18·40	2	0·93	1·87	2·81	3·75	4·68	5·62	6·56
		2½	1·17	2·34	3·51	4·68	5·86	7·03	8·20
		3	1·40	2·81	4·22	5·62	7·03	8·43	9·84
		3½	1·63	3·28	4·92	6·56	8·20	9·84	11·48
		4	1·87	3·75	5·62	7·50	9·37	11·24	13·12
66's	19·45	2	1·04	2·09	3·14	4·19	5·24	6·28	7·33
		2½	1·30	2·62	3·93	5·24	6·54	7·85	9·16
		3	1·57	3·14	4·71	6·28	7·85	9·42	10·99
		3½	1·83	3·66	5·50	7·33	9·16	10·99	12·83
		4	2·09	4·19	6·28	8·38	10·47	12·56	14·66
64's	20·65	2	1·18	2·36	3·54	4·72	5·90	7·08	8·26
		2½	1·47	2·95	4·43	5·90	7·38	8·85	10·33
		3	1·77	3·54	5·31	7·08	8·85	10·62	12·39
		3½	2·06	4·13	6·20	8·26	10·33	12·39	14·46
		4	2·36	4·72	7·08	9·44	11·80	14·16	16·52
60's	22·15	2	1·35	2·72	4·07	5·43	6·79	8·15	9·50
		2½	1·69	3·40	5·09	6·79	8·49	10·18	11·88
		3	2·03	4·07	6·11	8·15	10·18	12·22	14·26
		3½	2·37	4·75	7·13	9·50	11·88	14·26	15·63
		4	2·71	5·43	8·15	10·86	13·58	16·30	19·01
58's	24·25	2	1·63	3·26	4·89	6·52	8·15	9·78	11·41
		2½	2·04	4·08	6·12	8·16	10·20	12·24	14·28
		3	2·44	4·88	7·32	9·76	12·20	14·64	17·08
		3½	2·85	5·70	8·55	11·40	14·25	17·10	19·95
		4	3·26	6·52	9·78	13·04	16·30	19·56	22·82
56's	27·25	2	2·05	4·10	6·15	8·20	10·25	12·30	14·35
		2½	•2·57	5·14	7·71	10·28	12·85	15·42	17·99
		3	3·08	6·16	9·24	12·32	15·40	18·48	21·56
		3½	3·59	7·18	10·77	14·36	17·95	21·54	25·13
		4	4·11	8·22	12·33	16·44	20·55	24·66	28·77

a particular staple length area, coincides with the fixed quality number. In this position the arrow for the length points to the value for the fleece weight. For instance, a fibre fineness of 64's quality and 3 inch staple length, produces

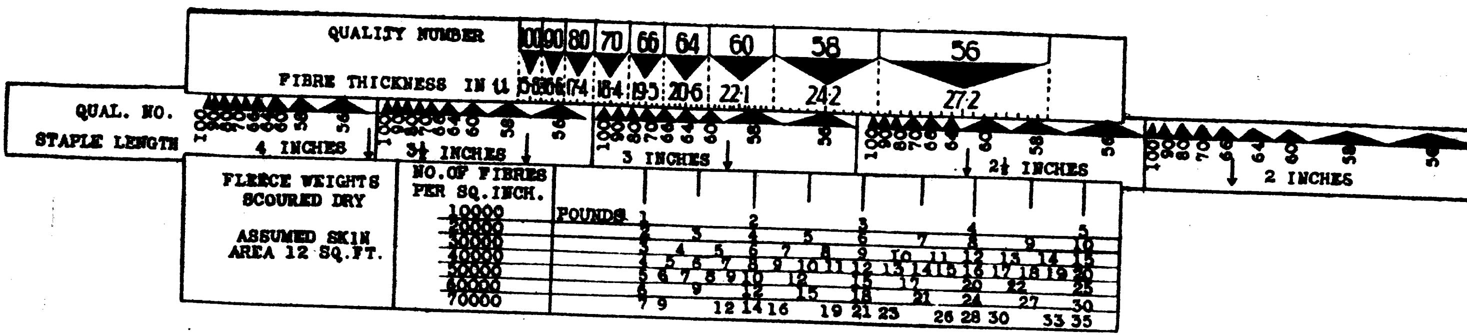


Fig. 3. The Merino Slide Rule

The Merino Slide Rule is used to estimate the scoured fleece weights of Merino sheep from values for quality number, staple length and number of fibres grown per square inch of skin. The Rule is set for a stud ram that produces a 64's fleece and a three-inch staple length. If such a ram has 30,000 fibres per square inch, it produces 5·25 pounds of scoured wool, as indicated by the arrow. At 40,000 fibres per square inch it produces 7 pounds of scoured wool. The Rule is of particular value in determining what influence each fleece characteristic exerts on wool production.

1·75 pounds fleece weight for 10,000 fibres per square inch and 5·25 pounds for 30,000 fibres per square inch. When fibre fineness, length, number of fibres per square inch of skin and skin area are known, it is possible to determine the clean dry weight of any merino fleece. Adjustments are however necessary where the skin area differs from that given on the slide rule.

(*c*) *Application of the Merino Slide Rule.* The rule is of technical interest to the merino breeder. In so far as the practical man is concerned, its use is at present limited, as the different fleece characteristics must necessarily be estimated by laboratory methods. Its application is useful in experimental work, where fibre fineness, length, number of fibres per unit area of skin and total skin area are usually determined on the live animals.

Several workers have estimated the skin area of sheep and other animals in studies on metabolism, e.g., Wood and Capstick (1926) ; Cowgill and Drabkin (1927). A comparison of the formulae and methods used for merino sheep is given by Lines and Peirce (1931) and Peirce (1934), who find the formula $A=9$ KW $2/3$, where K varies according to the flock from which the individual came, most reliable.

Table IV
A Comparison between the Wool Production of Low and High Producers on the Basis of their Relevant Fleece Attributes

Weight of Wool (Approx.) produced on an assumed skin area of 12 sq. feet.	Quality Number	Staple length (with crimp ratio 1·4)	No. of fibres per square inch
3	80's	2½	30,000
3	70's	3	20,000
3	64's	2½	20,000
5	80's	3	40,000
5	70's	3½	30,000
5	64's	4	20,000
5	64's	2	40,000
7	80's	3½	50,000
7	70's	3	50,000
7	64's	3	40,000
7	60's	3½	30,000
10	80's	3½	70,000
10	70's	3½	60,000
10	64's	3½	50,000
10	60's	3½	40,000
10	58's	4	30,000
12	70's	3	90,000
12	64's	3	70,000
12	64's	4	50,000
12	60's	3	60,000
12	60's	3½	50,000

These authors suggest the formula: $A=0{\cdot}117\ W^{0.59}$ or $0{\cdot}0882\ W^{2/3}$ for wethers, and $A=0{\cdot}126\ W^{0.59}$ or $0{\cdot}0955\ W^{2/3}$ for ewes, and find a surprisingly close agreement on Australian merino sheep between the values obtained by the formula and those obtained by the actual measurement of the area of the skin of the slaughtered animal.

A difficulty is experienced, however, in the wrinkly type of merino where, on account of the presence of skin folds, the estimation of the total skin area can only be approximate.

The rule is of particular value in determining the influence that each characteristic exerts on the fleece weight, and affords a method of determining the stress that each characteristic deserves in sheep selection. Examples are given in Table IV where the production of fleece weights (scoured dry) range from

three to twelve pounds and the production of low and high producers with their relevant fleece attributes is compared.

Tests to compare the values for scoured fleece weight with that obtained by the actual scouring, show an agreement which is of sufficient accuracy for practical use. Results of tests made are given in Table V.

Table V
A Comparison between the Fleece Weights determined by the Merino Slide Rule and the Fleece Weights determined by Shearing and Scouring

Ewe No.	Average fibre fineness (μ)	Average Staple Length Inches	Average No. of Fibres per sq. in.	Weight of sheep Pounds	Skin Area A-0909 W^2 sq. ft.	Fleece Calc. by MSR Pounds	Weight Shorn and Scoured Pounds
328	21·21	2·50	37,400	95·0	12·03	5·6	5·7
403	20·99	2·83	34,800	82·5	10·93	5·1	5·3
312	21·06	2·75	30,100	96·0	12·09	4·9	4·7
387	22·39	2·80	28,000	103·0	12·69	5·6	5·5
407	21·72	2·71	32,500	74·5	10·21	5·1	5·2

The mean fibre fineness of the fleece, obtained by sampling the sheep on different regions of the skin, is given. (Owing to variation in quality distribution over the fleece, Duerden and Bell (1931), samples were taken from the shoulder, side, britch and belly regions and a mean fineness thus obtained). Mean measurements for staple length are included since there are variations in length (Palmer (1931) ; Duerden and Palmer (1932)). The means for number of fibres per square inch are given since a variation also occurs in this respect (Botha (1930) ; Duerden and Botha (1930)). The method of sampling a fleece is similar to that used by Burns (1933), who also took into account different regions in the fleece in order to obtain a representative mean for the fleece.

The methods of scouring are those of Wilson (1928) and Botha (28). There is a close agreement between the fleece weights obtained by the two methods, and, where the fleece characteristics of a merino are known, the Slide Rule can be reliably used.

(*d*) *The Relative Importance of Fleece Characteristics in Wool Production.* The fleece weight varies directly with each fleece attribute. On a skin area of 12 square feet and with 40,000 fibres per square inch, every half an inch increase in staple length, makes a difference of 0·9 pounds in the fleece weight when this is a 70's, and 1·4 pounds difference when it is a 60's quality number. Furthermore, with 40,000 fibres per square inch, a staple length of 3 inches and the same skin area, there is a difference of 3 pounds fleece weight between an 80's quality number and a 60's quality number. Under the same conditions of staple length and skin area, every 10,000 fibres per square inch add 1·3 pounds to the fleece weight when this is an 80's, 1·4 pounds when it is a 70's, 1·8 pounds when it is a 64's, and 2 pounds when it is a 60's quality number.

Numerous fleece analyses of South African merino sheep have shown that the high wool producers, or stud sheep, differ from the low wool producers, of flock sheep, mainly in the number of fibres growing per unit area of skin (Bosman (1934)). Stud sheep produce from 30,000 to 60,000 fibres per square inch and flock sheep from 15,000 to 25,000 fibres per square inch.

In a flock sheep that produces a 70's quality wool, and 20,000 fibres per square inch, every half inch of staple length adds 0·47 pounds of scoured wool or 1·8 pounds of greasy wool (40 per cent. yield) to the fleece. Such a sheep with a three inch staple length produces 2·82 pounds of scoured wool or seven pounds of greasy wool (40 per cent. yield). An addition of half an inch staple length to a similar sheep is equivalent to the addition of 3,300 fibres per square inch to the skin of the sheep. Since a three inch staple length for twelve months growth seems to be the limit for the flock average, it follows that an increase in

wool production depends mainly on an increase in the number of follicles grown per square inch of skin. If the seven pounds greasy weight is to be increased to ten pounds greasy weight, an increase of 8,400 follicles per square inch is necessary, and the sheep will then carry 28,400 fibres per square inch instead of 20,000 fibres per square inch.

In a high wool producer or stud merino, the relative quantities are slightly different. On an animal that produces forty thousand fibres per square inch and a 66's quality fleece, every half inch increase adds 1·05 pounds of scoured wool, or 2·6 pounds of greasy wool (40 per cent. yield) to the fleece. Such a sheep with a four inch staple length produces 8·4 pounds of scoured wool or 21 pounds of greasy wool (40 per cent. yield). The addition of half an inch staple length to a similar stud sheep is equivalent to an increase of 5,000 fibres per square inch to the skin. Since a four inch staple length is considered a maximum length for a twelve months' growth in stud sheep, any increase in the wool production of such a ram depends mainly on an increase in the number of follicles grown per square inch.

In a stud sheep that produces a 64's quality wool and fifty thousand fibres per square inch of skin, every half inch increase in staple length adds 1·48 pounds to the scoured fleece, or 3·7 pounds to the greasy weight (40 per cent. yield). Such a sheep, with a three inch staple length produces 8·85 pounds of scoured wool or 22·1 pounds of greasy wool (40 per cent. yield). This increase is equivalent to the addition of 8,400 fibres per square inch to the skin of the animal, when a three inch staple length is considered. If such a sheep were required to produce 26 pounds of grease wool (40 per cent. yield), it would be necessary for it to carry 60,000 fibres per square inch of skin.

Numerous other comparisons of the wool characteristics can be made, and since economic fleece production is dependent on the quantity and the quality of the individual fleeces, these comparisons are invaluable to the merino breeder.

B. FACTORS THAT INFLUENCE WOOL PRODUCTION

(*a*) *Nutrition*. Feed plays an important part in wool production. The sheep farmer is aware that during droughts his sheep are lighter in body weight, and produce lighter and finer fleeces. Different research workers have investigated the influence of feed on the sheep and its fleece.

Probst (1926) found that the variation of wool growth along a staple from one of his stud rams could be explained by the influence of winter feed conditions. Wilson (1927) in dealing with wool production in California stated that "sheep which are improperly and poorly fed produce light frowsy fleeces lacking the life which is so essential to good wool." Duerden and Bosman (1927), found an absence of uniformity of growth along a wool staple which was presumed to have resulted from feed influences. Hardy and Tennyson (1930), in describing wool fineness, influenced by rate of growth, showed that the period of greater growth was associated with a general thrifty condition of the sheep, also that the weight of wool increased with an increase in length and fibre fineness. Wilson (1931), found considerable differences in the fleece characteristics when three Romney wethers were fed on maintenance rations and then on sub-maintenance rations. Weber (1931), found a difference in scoured fleece weights, fibre fineness and length by feeding different quantities of ground corn and alfalfa to sheep. Snell (1931), found a significant effect on rate of growth, diameter and crimp of wool fibres by changing the planes of nutrition.

(*a*) *The Influence of Feed on Quantity and Quality of Wool.* Recently an experiment* designed to determine the influence of nutrition on the fleece of the South African merino was carried out at the Grootfontein School of Agriculture. In this experiment the influence of different planes of nutrition on two groups

* The author is indebted to Mr. Maré of the Grootfontein School of Agriculture, who collaborated in this experiment, and was responsible for the management, the feed and body weights of the sheep.

of merino hamels is shown in respect of body weight, fleece weights and fibre fineness. The sheep were fed on lucerne hay, mealies, oats and saltbush, these being common feeds used by the South African farmer.

Twenty-four, three year old merino hamels bred and reared on Karroo veld were selected from the Grootfontein flocks. The sheep were subjected to a preliminary feeding period of four weeks and were then divided into two groups of eleven each, two of the hamels being discarded as they reacted unfavourably to the rations.

Selection of the groups was based on body weights and a macroscopic examination of the fleece so that the groups were similar. The lots, recorded as 26 and 27, were then shorn and shoulder samples of each sheep analysed in the laboratory. One animal of lot 27 died at the commencement of the experiment and one of lot 26, after nine months.

Each group was subjected to a different plane of feeding, 26 receiving a sub-maintenance ration, and 27 a full ration. Each lot was confined to a small enclosure 28 by 36 feet in which housing was provided with suitable feeding troughs and clean drinking water.

There were two distinct feeding periods. For the first nine months 26 received a sub-maintenance ration and 27 a full ration. For the second nine months half of lot 26 was placed on a full ration, and the remainder treated as before. Half of 27 was retained on a full ration and the remainder on a sub-maintenance ration. In this way for the second feeding period groups 26 and 27 each consisted of five well fed and five underfed sheep, and served as a confirmatory test to the first nine months period. The regrouping of lots 26 and 27 therefore resulted in:

5 sheep well-fed for 18 months.
5 sheep underfed for 18 months.
5 sheep well-fed for 9 months and then underfed for 9 months.
5 sheep underfed for 9 months and then well-fed for 9 months.

Body weights were recorded weekly after the usual starvation period of fifteen hours. Shoulder wool samples were analysed periodically and the weights of fleeces recorded at shearing.

The feed consisted of lucerne hay, crushed yellow mealies, whole oats and fresh Oldman Saltbush. To this ration was added a mixture of salt and bone-meal in the proportion 1:2. All feed was weighed before each feeding, which took place twice a day. The animals consumed all of their daily ration, an analysis of which is given in Table VI. The rations are given as averages for the periods mentioned and slight variations are not recorded.

The experimental results for the first and second nine months are summarised in Table VII, and the mean values obtained for body weights, fibre fineness and fleece weights are compared.

As regards body weights, lot 26, the underfed group, was reduced by 15·8 per cent. Lot 27, the well-fed group gained 10·8 per cent. The body weights are given as shorn weights and the wool grown during the nine months is not included.

Since there was no significant difference between the two groups initially, the difference after treatment which amounted to 26·6 per cent. is appreciable. Lot 26, the underfed group, was subdivided into 26C and 26D, the former being continued on the sub-maintenance ration. At the end of another nine months 26C had lost a further 9·9 per cent. in weight. Lot 26D a sub-section of lot 26 which was formerly underfed, was then well-fed for nine months and increased from 66·4 to 88·6 pounds, or to the extent of 32·0 per cent.

Lot 27C that was formerly well-fed, was after nine months of underfeeding, reduced by 18·4 per cent. Lot 27D, which continued to be well fed, gained 13·2 per cent. It is thus shown that body weights can be appreciably changed at will by regulating the food consumed.

Table VI. The Average Daily Ration per Sheep in the Experiment "Influence of Nutrition on Wool Production."

Period	Lot	Treatment	Ration in Ounce					Nutrients in Pounds.			
			Lucerne	Mealies	Oats	Saltbush	Bonemeal and salt	Total Dry Matter	Digestible crude Protein	Total Digestible	Nutritive Ratio.
Preliminary ...	26 & 27	Well-fed ...	8	10	4	0	1	1·23	0·13	0·96	6·65
First 9 months ...	26	Under-fed ...	5	5	3	6	1	0·82	0·09	0·59	5·87
	27	Well-fed ...	8	10	4	8	1	1·35	0·14	1·01	6·21
Second 9 months ...	26C	Under-fed ...	4	4	3	6	1	0·71	0·07	0·51	5·78
	26D	Well-fed ...	8	10	4	8	1	1·35	0·14	1·01	6·21
	27C	Under-fed ...	4	4	3	6	1	0·71	0·07	0·51	5·78
	27D	Well-fed ...	8	10	4	8	1	1·35	0·14	1·01	6·21

Table VII. The Influence of Differing Planes of Nutrition on Body Weights, Fleece Weights and Fibre Fineness

	First Nine Months			Second Nine Months		
	Lot 26 Under-fed	Lot 27 Well-fed	Lot 26C Under-fed	Lot 26D Well-fed	Lot 27C Under-fed	Lot 27D Well-fed
Body Weights—pounds (Initial)	83·0 ± 2·21	85·1 ± 2·51	76·5 ± 2·36	66·4 ± 1·70	96·5 ± 4·65	92·0 ± 1·69
Body Weights—pounds (After treatment) ...	69·9 ± 1·89	94·3 ± 2·52	68·9 ± 3·10	88·6 ± 3·53	78·8 ± 2·97	104·3 ± 3·22
Increase (per cent.)	− 15·8	+ 10·8	− 9·9	+ 32·0	− 18·4	+ 13·2
Fibre Fineness (μ) (Initial)	17·9 (805)	17·7 (805)	15·0 (1205)	13·6 (1505)	17·7 (805)	16·2 (905)
Fibre Fineness (μ) (After treatment)... ...	14·6 (1505)	17·3 (805)	14·7 (1505)	17·7 (805)	13·5 (1505)	16·9 (905)
Increase (per cent.) (as cross-sectional area)	− 33·4	not significant	not significant	+ 69·3	− 41·8	not significent
Fleece Weights—pounds (After treatment)...	—	—	4·21	4·65	4·76	5·55

As regards fibre fineness, lots 26 and 27 commenced the experiment with an initial fineness of 17·9μ and 17·7μ respectively, there being no significant difference between the values. Lot 26 was underfed for nine months and reduced to 14·6μ, a reduction of 33·4 per cent., the wool being changed from an 80's to a 150's quality number. Lot 27 which was well fed or nine months, showed no significant difference between the initial and final quality numbers.

Lot 26C, a subdivision of 26, which continued to be underfed, maintained a reduced fibre finenes and did not change appreciably. When, however, 26D, the remaining portion of 26, was well fed, an increase of 69·3 per cent was recorded and the wool changed from a 150's to an 80's, the same extent of change as that recorded in lot 26 for the first nine months of the experiment.

A similar result was obtained from lot 27C, which was formerly well fed and then underfed, an 80's wool becoming a 150's, a reduction of 41·8 per cent. in fineness.

Lot 27D, which continued to be well fed, did not change appreciably.

It is thus shown that in the merino fibre fineness is extremely sensitive to changes in the food consumption. A graphic representation of the experimental results, recorded throughout the 18 months, is shown in Fig. 4.

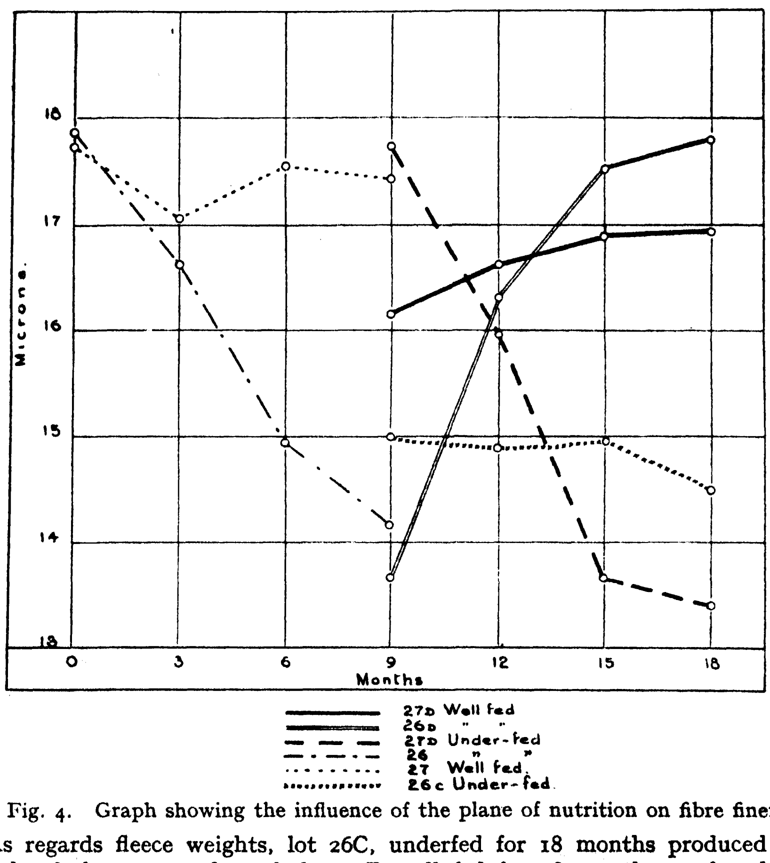


Fig. 4. Graph showing the influence of the plane of nutrition on fibre fineness.

As regards fleece weights, lot 26C, underfed for 18 months produced 4·21 pounds of clean scoured wool, lot 27D well fed for 18 months produced 5·55 pounds of clean scoured wool, a difference of 31·8 per cent. A comparison between the results obtained from lots 26D and 27C is not so reliable since the respective groups did not receive the same treatment during the whole of the 18 months. It is, however, interesting to note that lot 26D which was underfed for nine months and then well fed for nine months, produced 4·65 pounds of clean

dry wool, or, 10 per cent. more wool than lot 26D, which was underfed for the whole period.

Lots 26D and 27C were both underfed for nine months and well fed for nine months and there is not an appreciable difference between their clean scoured fleece weights.

By controlling the feed of the sheep and not shearing for eighteen months, it was possible to produce the first nine months' growth of the staple under one plane of nutrition and the other nine months growth under a changed plane of nutrition. It was thus possible to study the influence of changes in nutrition on one and the same fibre.

Three fibres A, B and C are shown in figure 5. Fibre A from 27C was well fed for the first nine months and measured 35μ. It was then underfed and reduced to 25μ. Fibre B, from 26D, when underfed, measured 22·5μ and when well fed, measured 27·5μ. Fibre C, from 27D showed no change throughout the eighteen months when well fed for the whole of the period. It measured 35μ throughout.

It is interesting that, depending on the plane of nutrition of the sheep, differing quality numbers can be produced in the same staple. Some of the results of fibre analysis are summarised in Table VIII.

Table VIII

To show the Changes that take place in the Same Staple of Wool when Merino Sheep are subjected to Differing Planes of Nutrition

Sheep No.	Well-fed Region. Mean fineness (μ) of 250 fibres.	Qual. No.	Under-fed Region Mean fineness (μ) of 250 fibres.	Qual. No.
514	16·68	90's	13·13	150's
526	17·76	80's	13·03	150's
561	20·16	64's	14·15	150's
553	19·31	66's	15·70	100's
545	17·04	80's	15·10	120's
520	15·22	120's	14·14	150's

It is seen that individual sheep can produce extreme variations in the quality numbers of their fleeces as a result of differing planes of nutrition. A 64's wool can be changed to a 150's by malnutrition, a 66's wool can be reduced in fineness to a 100's, whilst an 80's and 90's can be refined to a 120's or 150's.

As regards reduction in fleece density, due to the reduction in fineness, it is shown that in extreme cases there is a diminution of 36 per cent.

The Influence of Feed on Fibre Contour. The spinning property of wool is influenced by fibre contour (Barker and Burgess (1928)) and it was therefore decided to determine to what extent the contour of merino wool is influenced by starvation periods such as do occur in South Africa during seasons of drought.

In the preceding experiment on the influence of feed on fibre fineness, wool staples of eighteen months' growth, consisted of a nine months' starvation growth and nine months' growth with an abundance of feed and the same staple could, therefore, be studied when starved and when well fed. The technique employed for cutting sections for the determination of fibre contour was that used by Barker and Burgess. The results are summarised in Table IX.

The results show that feed has no influence on fibre contour. The comparisons are made on the same strand of wool and the individuality of different staples and of different sheep is thereby eliminated. Since feed does not influence contour, it must be concluded that the characteristic is of genetic origin, and an improvement in fibre contour can be obtained only by breeding towards that end.

(*b*) *The Seasonal Influence on Merino Wool Production.* The fleece of the merino sheep, unlike that of many other domestic mammals in which winter and

Table IX
An Analysis of the Influence of Feed on Fibre Contour

Sheep No.	Treatment.	Mean fineness (μ) of 500 fibres.	Contour $\frac{A}{B}$ Mean of 500 fibres.
541	Well-fed	18·09	1·26
	Underfed	12·03	1·25
520	Well-fed	15·16	1·28
	Underfed	14·19	1·28
517	Well-fed	16·97	1·33
	Underfed	15·57	1·33
531	Well-fed	17·00	1·22
	Underfed	16·21	1·22
540	Well-fed	17·88	1·10
	Underfed	15·32	1·11

summer changes take place, grows continuously from month to month and from year to year.

In the horse, cow and donkey, seasonal variations occur (Duerden and Whitnall (1930)). Among the ovidae, seasonal shedding takes place in Ovis ammon poli (Crew (1921)), the Blackhead Persian (Boyd (1927)), the Auodad and Mouflon sheep (Duerden and Seale (1927)), the Welsh mountain sheep (Roberts (1926)), and the British Mountain Breeds (Duerden (1927 ; 1929)), all these being representative of the more primitive type of coat.

The merino sheep, with its specialised fleece, has lost the power of seasonal shedding and, unlike its ancestors, has continuously growing follicles. It was not known however whether the fleece was influenced by seasonal changes and an analysis is here outlined of the winter and summer growths of three merino wethers that were maintained at the Grootfontein School of Agriculture, Middelburg, Cape, where extreme winter and summer climatic variations occur. Since a change in nutrition has a marked influence on merino wool growth the experimental sheep were stall-fed.

The material for study was obtained from three, forty-months-old merino wethers (fig. 6) which from birth were stall-fed on a balanced ration and were never shorn. The changes in winter and summer pasturage were thus eliminated and it was possible to study the same staple of wool for consecutive seasons for three years, and also to compare the yearly growth for the first three years of the sheep's life.

The staples from the sheep were approximately twenty-five centimetres, or ten inches, in staple length. The first seven months' growth of the staple was not taken into account, since this portion, representing the coat of the lamb, is not comparable with the fleece grown by the adult merino (Botha (1930)). The remainder of each staple was divided into cuttings corresponding to the winter and summer growths. The guide for identifying the regions was obtained from clippings taken at monthly intervals and used subsequently in a study of the monthly rate of growth. It was thus possible to identify accurately the seasonal and yearly growths in the same staple and to determine any changes in the regions.

The cuttings of the winter and summer growths were scoured by the benzene-saponin method (Miller and Bryant (1932)), and dried to constant weight in regain bottles (Barritt and King (1926)). The dry weights are summarised in Table X. An estimate of the number of fibres in each cutting was made and the fibre fineness calculated. (With the clippings available it was found convenient to use Roberts' weight-length method since the weights of wool produced during summer and winter could also be compared).

The Seasonal Changes in the Karroo. In the Karroo there are varying factors that influence climate, such as temperature, humidity, sunshine, wind, etc. Meteorological observations for temperature, rainfall, sunshine and wind at the

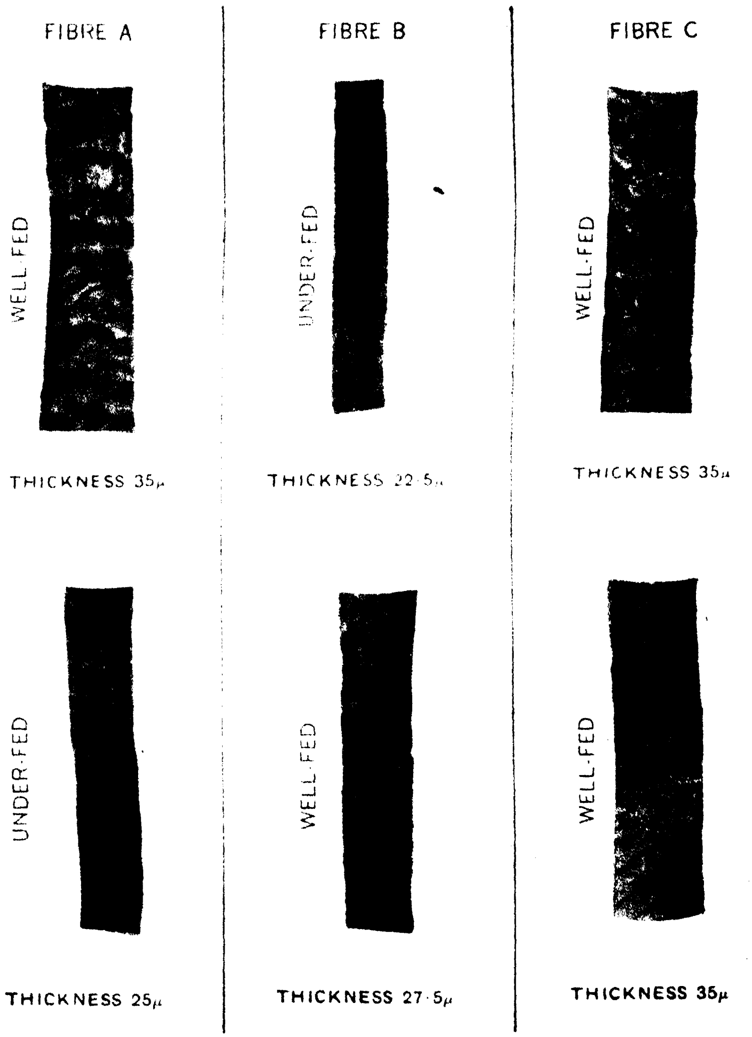


Fig. 5. Photomicrographs showing the influence of feed on one and the same fibre.

Face p.286

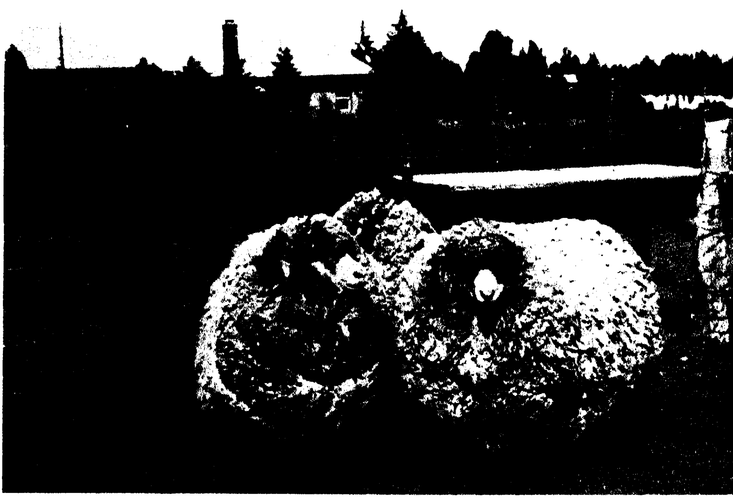


Fig. 6. Plate showing three forty months old merino wethers that were never shorn.

Grootfontein School of Agriculture were available and each of these shows seasonal variations which are summarised in Table X.

Table X
The Wool Analyses of Winter and Summer Growth of Merino Sheep that were never shorn and the relevant Seasonal Meteorological Records

	Winter, 1931	Summer, 1931/32	Winter, 1932	Summer, 1932/33	Winter, 1933	Summer, 1933/34
SHEEP No. 1 ...						
Dry Wt. (gms.) ...	0·4260	0·4288	0·4291	0·4253	0·4285	0·4265
Fibre Fineness (μ)	20·8	20·9	20·9	20·7	20·9	20·8
SHEEP No. 2						
Dry Wt. (gms.) ...	0·3978	0·3959	0·3988	0·3975	0·3984	0·3960
Fibre Fineness (μ)	18·7	18·6	18·7	18·7	18·7	18·6
SHEEP No. 3						
Dry Wt. (gms.) ...	0·4455	0·4480	0·4472	0·4450	0·4463	0·4485
Fibre Fineness (μ)	18·1	18·2	18·1	18·1	18·1	18·2
Meteorological Records at Grootfontein (Averages)						
MAXIMUM	62·7	83·7	64·7	84·9	63·0	77·9
(degrees F.)						
MINIMUM ...	33·5	53·1	36·5	51·6	31·3	53·3
Sunshine Hours ...	8·0	11·2	8·5	11·1	8·2	9·2
Rainfall (inches) ...	3·21	6·60	1·08	3·32	0·82	12·5
Wind (miles per hr.)	3·5	3·6	4·2	3·5	5·0	2·9

As regards temperature, an extreme variation typical of the Karroo, is shown. The four winter months of May, June, July and August were regarded as the coldest period, against the four summer months of November, December, January and February, which constitute the hottest period of the year. Although the average maximum and minimum temperatures in the table vary from 31·1°F. to 84.9°F., larger individual variations were recorded and the maximum often reached 90°F. in the shade and the minimum temperature as low as 15°F. or 17 degrees of frost.

As regards sunshine, the meteorlogical observations show a seasonal variation of from 8·0 to 11·2 in sunshine hours. This figure, however, does not indicate the intensity of sunlight, and records concerning the latter were not available.

Observations on rainfall for the same four-monthly periods show a variation of from 1·08 inches to 12·5 inches. Rainfall influences the nutritional value of the pasturage but in this case the sheep were stall-fed and the rainfall therefore does not have the same influence on wool growth as when the animals are run on the veld.

As regards wind force, the winter months of 1932 and 1933 show a higher rate per hour than the summer months of these years. Although the average of the wind force is not higher than five miles per hour, twenty miles per hour was frequently recorded.

The variations in the seasonal factors are shown to be appreciable, and whether these factors have an influence on merino wool production has long been a controversial topic among wool farmers.

Experimenal Results: The wool analyses of the experiment are summarised in Table X. As regards the dry weights of the wool cuttings, there is no significant difference between the consecutive seasons or between the consecutive years, the difference shown being well within experimental error. As regards fibre fineness, no difference is shown between the winter and summer growths nor between the yearly growths. It must, therefore, be concluded that the seasons have no influence on wool fineness in the Karroo, provided the feed is kept constant. There is also no difference in fibre fineness from year to year for the first three years under similar conditions of feed. (The lamb's coat representing the first seven months of growth was disregarded).

As regards length, several workers have shown that the rate of growth is constant from month to month (Burns (1931) ; Fraser (1931)), and from year to year (Duerden and Maré (1931)) if the feed is kept constant. It follows therefore, that in the Karroo at least, provided the nutrition is not changed, there is no seasonal influence on the dimensional attributes of fineness and length, which affects the volume of wool produced by merino sheep.

It must be pointed out that these results apply only for Karroo areas. In other regions of South Africa differing results may be obtained, and to investigate these possibilities, more comprehensive experiments have been undertaken.

(*c*) *Pregnancy and Lactation.* The wool farmer is aware that the fleeces of merino ewes are influenced by the suckling of lambs and that the basal metabolism of the sheep is greatly affected during pregnancy and lactation. In discussing the basal metabolism of the Australian merino sheep, Lines and Peirce (1931), conclude that pregnancy did not appear to increase the metabolism up to a time when three-fifths of the normal term had elapsed. Duerden, Bosman and Botha (1932), while comparing wool fineness produced by sheep on a phosphorus sufficient diet with that produced on a phosphorus deficient diet, concluded that a finer fibre is grown during the lactation period than during the period of gestation. In the latter experiment, the sheep were stall-fed and the lambs were weaned from their mothers three weeks after birth. In practice, however, the merino lamb is usually weaned at the age of four months, the longer suckling period influencing the basal metabolism and wool growth differently from that shown in the latter experiment. Since the influence of pregnancy and lactation on merino wool under farming conditions has not been recorded in South Africa, such a study is here described. The sheep were maintained in the Karroo, this area constituting the largest portion of the Union's wool producing country.

Wool samples of twelve months' growth were taken from the shoulder regions of twenty-six merino stud ewes that were maintained at the Grootfontein School of Agriculture which is the centre of the Karroo area. Accurate records as regards shearing, service by rams and lambing were kept, and it was possible to identify the zones in the staple that corresponded to the periods of pregnancy and lactation. Thirteen of the ewes lambed and the remainder served as controls. The ewes with lambs were placed on slightly better pasturage after lambing, in accordance with general farming practice. Otherwise all the sheep received similar treatment. A fibre analysis of each sample was made at two regions along the staple corresponding to the growth periods of pregnancy and lactation. Similar zones were taken from the staples of the dry ewes.

Experimental results. The fibre fineness and quality numbers of the analysis are summarised in Table XI. On the left-hand side of the table are given the results from the ewes with lambs and a distinction is made between the periods of pregnancy and lactation. On the right-hand side of the table are given the results from the ewes without lambs, and the upper and lower growths of the staples, corresponding to the growth periods of lactation and gestation respectively, are distinguished.

In general, the fibre measurements and quality numbers are finer during lactation than during gestation, except in sheep numbers 4 and 24, where this difference is not significant as is shown by the probable errors of the mean. In sheep number 12 there was an increase of 7·5 per cent. in fibre fineness. The ewes with lambs show a refining varying from 11·7 to 24·2 per cent., the difference being based on the cross-sectional areas of the fibres. As regards quality numbers, the differences between regions are summarised as follows:—

a 58's quality number was refined to a 64's quality number.
a 60's ,, ,, ,, 66's or 70's quality number.
a 64's ,, ,, ,, 66's quality number.
a 66's ,, ,, ,, 70's or 90's quality number.
an 80's ,, ,, ,, 90's quality number.

Table XI

Comparison of the Fibre Fineness produced during Pregnancy and Lactation and the Normal Growth of the Fleece of Merino Ewes

Ewe No.	Ewes with Lambs. Pregnancy period: Fibre fineness in μ (Mean of 250 fibres)	Pregnancy period: Quality number	Lactation period: Fibre fineness in μ (Mean of 250 fibres)	Lactation period: Quality number	Difference (Percentage)	Ewe No.	Ewes without Lambs. Upper growth: Fibre fineness in μ (Mean of 250 fibres)	Upper growth: Quality number	Lower growth: Fibre fineness in μ (Mean of 250 fibres)	Lower growth: Quality number	Difference (Percentage)
1	19·68 ± 0·13	66's	18·49 ± 0·11	70's	−11·7	5	20·14 ± 0·13	64's	21·07 ± 0·14	64's	+ 9·4
3	19·36 ± 0·16	66's	18·14 ± 0·13	70's	−13·6	6	17·30 ± 0·13	80's	17·62 ± 0·12	80's	not significant
4	19·53 ± 0·10	66's	19·74 ± 0·10	66's	not significant	8	19·78 ± 0·11	66's	20·87 ± 0·11	64's	+11·3
7	21·32 ± 0·14	64's	19·89 ± 0·12	66's	−12·9	10	20·51 ± 0·14	64's	21·01 ± 0·15	64's	not significant
9	20·31 ± 0·16	60's	18·27 ± 0·13	70's	−19·1	11	20·25 ± 0·14	64's	20·99 ± 0·12	64's	+ 7·4
12	21·09 ± 0·18	64's	21·87 ± 0·16	64's	+ 7·5	15	21·33 ± 0·15	60's	22·02 ± 0·13	60's	+ 6·6
13	19·84 ± 0·12	66's	18·05 ± 0·11	70's	−17·2	16	20·78 ± 0·14	64's	21·04 ± 0·13	64's	not significant
14	21·83 ± 0·14	60's	19·62 ± 0·14	66's	−19·2	17	22·15 ± 0·12	60's	22·46 ± 0·13	60's	,, ,,
20	17·67 ± 0·11	80's	16·50 ± 0·11	90's	−12·8	19	20·08 ± 0·16	64's	20·45 ± 0·13	64's	,, ,,
22	17·64 ± 0·12	80's	16·22 ± 0·11	90's	−15·4	23	21·80 ± 0·15	64's	22·50 ± 0·15	60's	+ 6·5
24	21·02 ± 0·16	64's	20·44 ± 0·15	64's	not significant	25	19·51 ± 0·14	66's	21·72 ± 0·14	64's	+23·9
29	19·27 ± 0·16	66's	16·78 ± 0·12	90's	−24·2	26	19·22 ± 0·16	66's	19·33 ± 0·16	66's	not significant
30	23·95 ± 0·17	58's	21·19 ± 0·14	64's	−21·7	27	20·98 ± 0·13	64's	21·51 ± 0·12	60's	+ 5·1
Mean	20·19 ± 0·04	64's	18·86 ± 0·04	70's	−12·7	Mean	20·29 ± 0·04	64's	20·97 ± 0·04	64's	+ 6·8

When the group of ewes with lambs was considered as a whole, a mean fibre fineness of 20·19μ or a 64's quality number was recorded during pregnancy. During lactation this was refined to 18·86μ, or a 70's quality number showing a reduction in fibre fineness of 12·7 per cent.

In some of the ewes without lambs, the upper and lower growths were not significantly different. In others there was a slight increase in fibre fineness.

When the group of dry ewes is considered as a whole, the upper growth, corresponding to the pregnancy period of the ewes with lambs, measured 20·29μ or a 64's quality number. The lower growth, corresponding to the lactation period of the ewes with lambs, showed an increase in fibre fineness of 6·8 per cent. over the upper growth and measured 20·97μ or a 64's quality number. Presumably the lower growth of the dry ewes was produced under more favourable conditions of pasturage.

The pregnant ewes and the dry ewes were run in the same flock and received the same treatment, and the wool of the two groups did not differ significantly. During the pregnancy period the ewes with lambs averaged 20·19$\pm$0·04μ and the dry ewes 20·29$\pm$0·4μ. The probable errors calculated on 3,250 fibres measured in each group, showed no significant difference between the two groups. The shearing of the previous year similarly showed no difference between the two groups and it can, therefore, be assumed that a 64's quality number was, in this respect, the normal growth.

The lower growth of the dry ewes showed an increase of 6·8 per cent. in fibre fineness over the upper growth, and the same increase over the upper growth of the pregnant ewes, and was due to improved pasturage of the Karroo veld during the time. From this, it can be concluded that lactation has a greater influence on wool fineness than is indicated by the results obtained from the ewes with lambs. If the lower growth of the dry ewes is considered as the control then the decrease in diameter due to lactation was from 20·97μ to 18·86μ or a decrease of 19·1 per cent.

Conclusions. Pregnancy does not influence merino wool fineness, but during lactation when the lambs are suckled, a finer quality number is produced. A staple of wool from lambing ewes, will, therefore show no difference between the five months' growth produced during pregnancy and that produced normally. The four months' growth produced during lactation will be finer than either the normal growth or that grown during pregnancy.

The variation in fineness along the staple in lambing ewes is of importance to the merino judge and the breeder since an allowance is necessary for the change in fineness due to lactation. Not only is there a difference in fibre fineness between the two regions of pregnancy and lactation but also a difference in fleece density, since a reduction in fibre fineness influences the compactness of the fleece. It has been shown that the compactness of the merino fleece is dependent on the number of fibres growing per unit area of skin and their fineness and when the fineness is reduced, the degree of compactness is also reduced.

An analysis of the number of fibres grown per unit area on these ewes was available and a comparison of the reduction in fleece density, due to the refining of the fibre, is made in Table XII.

The fleece density, which is expressed as percentage skin area, is shown to be appreciably diminished during the lactation period when compared with the period of pregnancy. For example, it is shown that sheep number 30 was reduced in fleece density from 2·83 per cent. to 2·05 per cent., whilst number 9 was reduced from 2·48 to 1·72 per cent. The percentage reduction in fleece density ranges from 8·8 to 30·6 per cent. which, from the practical sheep judge's point of view, indicates an appreciable reduction.

A reduction in fibre fineness is also responsible for a reduction in the weight of the scoured fleece. The amount obtained by using the merino slide rule

Table XII
To illustrate the Reduction in Fleece Density and in Scoured Fleece Weights, due to Lactation and the Suckling of Lambs

Sheep No.	No. of fibres grown per sq. inch	Pregnancy Period		Lactation Period		Percentage reduction in fleece density.	Reduction in scoured fleece weight (pounds) due to reduction in fibre fineness (4 months' gestation)
		Quality Number	Fleece density as percentage skin area.	Quality Number	Fleece density as percentage skin area.		
30	39,300	58's	2·83	64's	2·05	27·5	0·7
14	47,700	60's	2·85	66's	2·20	22·8	0·6
9	41,700	60's	2·48	70's	1·72	30·6	0·7
7	45,100	64's	2·34	66's	2·06	11·8	0·3
3	59,700	66's	2·75	70's	2·45	10·9	0·3
29	45,600	66's	2·12	90's	1·53	27·8	0·6
22	67,900	80's	2·50	90's	2·28	8·8	0·3

(Section 11) on the experimental results, ranges from 0·3 to 0·7 pounds in the scoured state.

The change in fibre fineness produced by lactation is a factor to be considered where the fleece characteristics of the merino are studied from a genetic aspect. A clear distinction is necessary between the zone produced during pregnancy and that produced during lactation, since the latter is appreciably different from the normal growth.

III. THE FIBRE FINENESS OF SOUTH AFRICAN MERINO WOOL

It has long been accepted that South African wool is outstanding in fibre fineness. Up to the present, however, few data based on laboratory measurements have been available and it was not previously possible to express the fibre fineness of the South African clip in precise arithmetic terms. A study in which basic facts have been demonstrated, is here outlined.

A. COMMERCIAL WOOL

South African merino wool is produced under widely varying conditions, and a representative selection must be based on a large number of samples so that this variation is taken into account. For the present study the collection consisted of one thousand wool samples obtained from woolmen at the coastal ports and from South African wool farmers. The material was in the form of small and large wool samples and many represented an average selection from bales and clips. There were included wools grown under droughty conditions and in seasons of plenty, Karroo grown, Grassveld grown, and wools from all the four provinces of the Union of South Africa.

Individual samples were analysed for fibre fineness by the camera method (Duerden (1929)), and fibre fineness is expressed as mean fibre fineness or fibre width.

In order to obtain a representative mean fineness of the sample, a system of random sampling, which takes into account the variability of wool, was used. Each sample was divided into smaller lots and a random selection of staples taken from each, so that ultimately these consisted of 100 to 500 staples from the original sample, the number depending on the size of the sample. A wool strand was taken from each staple and all the strands were rolled together. These were further cut into small clippings from eight to ten places along the staple length so as to average up any variability along the length of the staple.

The small clippings were mixed in ether until a homogeneous mixture was obtained and the fibres were dried and mounted in Euparal for the measurement of 250 on a Zeiss Hegener micro camera.

The determination of fibre fineness by the camera method gives the frequencies of fibre fineness and from this the standard deviation and the coefficient of variability of each of the thousand samples was calculated. In this way it was possible to make a study of variability within the sample.

Fibre Fineness and Distribution. One quarter of a million fibres were measured, and the grouping of the fibre measurements, according to class intervals of 2·5μ, is shown in Table XIII, where the frequencies and percentage frequencies are given.

Table XIII

Fibre Distribution of a Quarter of a Million South African Merino Wool Fibres

Fibre fineness in μ.	Frequency	Percentage Frequency.	
7·5	330	0·13	
10·0	5013	0·20	
12·5	23869	9·48	
15·0	40737	16·18	83 per cent.
17·5	62082	24·66	
20·0	51882	20·61	
22·5	29325	11·65	
25·0	19524	7·76	
27·5	8350	3·32	
30·0	4943	1·96	
32·5	2963	1·18	
35·0	1228	0·49	
37·5	853	0·34	16 per cent.
40·0	245	0·10	
42·5	178	0·07	
45·0	84	0·03	
47·5	82	0·03	
50·0	62	0·02	
Total	251750		

Mean fibre fineness ... ... 19·10μ
Standard deviation ... ... 4·868μ
Coefficient of variability ... ... 25·5 per cent.

The finest fibre measures 7·5μ and the coarsest 50μ. Eighty-three per cent of the fibres range from 7·5μ to 22·5μ and the remaining sixteen per cent have their limits between 25μ and 50μ. The latter limits are coarser than a 60's quality number and are not strictly classified as merino.

The mean fibre fineness of all fibres is 19·10μ or a 66's quality number. The standard deviation is 4·868μ and the coefficient of variability is 25·5 per cent. The frequencies of the table are represented graphically in Figure 7.

The mode at 17·5μ shows a frequency of 24·6 per cent.

Quality Numbers. The frequencies and percentage frequencies of the quality numbers are summarised in Table XIV and Fig. 8.

The percentage frequencies show that whilst 92 per cent. of the samples fall strictly within merino quality numbers, eight per cent are coarser and are classed as crossbred. In the 25·8 per cent. of samples that range from 90's to 150's quality number are included the wools grown under droughty conditions, a portion of which are tender, although many have sufficient tensile strength to be passed as " sound ". The South African merino clip therefore includes a proportion of superfine wools that conforms to a fineness of 90's to 150's.

When classification is based on the fineness types adopted by the National Wool Growers' Association and classed as " strong ", " medium " and " fine "

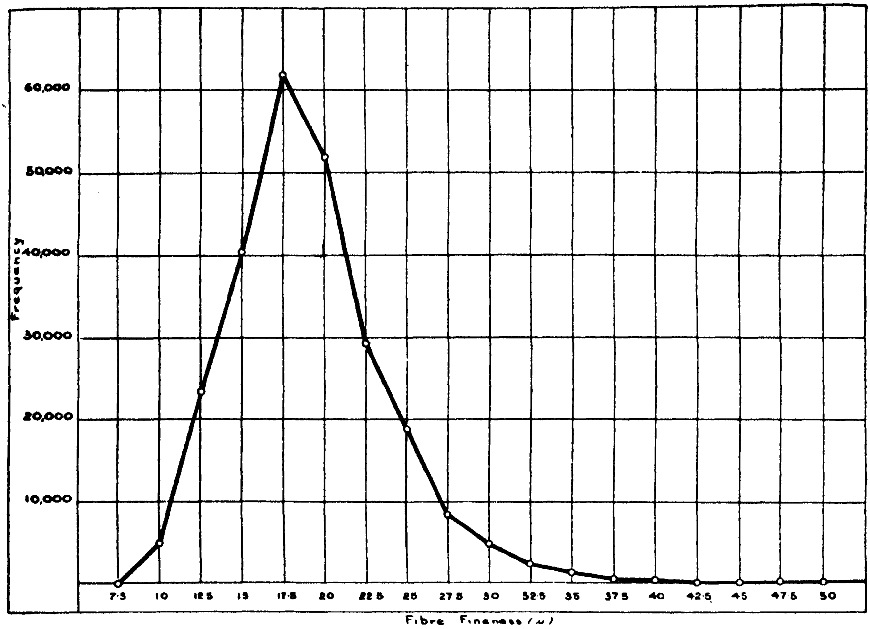


Fig. 7. Graph showing the frequency distribution, arranged according to fibre fineness, of a quarter of a million South African merino wool fibres.

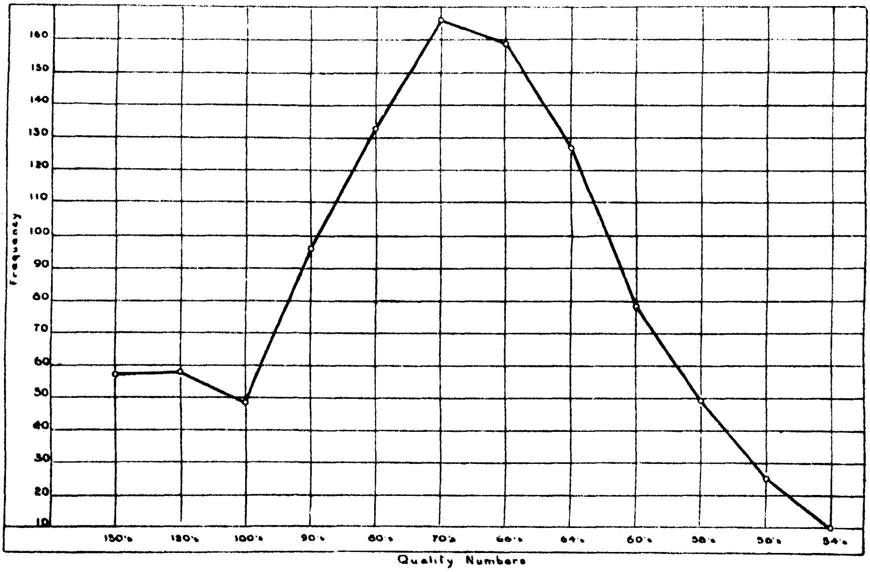


Fig. 8. Graph showing the frequency distribution arranged according to quality numbers, of a thousand South African wool samples.

Table XIV
The Quality Numbers of a Thousand South African Merino Wool Samples

Quality Number.	Frequency.	Per cent. Frequency.	
150's	57	5·7	92 per cent.
120's	58	5·7	
100's	49	4·9	
90's	96	9·5	
80's	133	13·2	
70's	166	16·5	
66's	159	15·8	
64's	127	12·6	
60's	79	7·8	
58's	50	5·0	8 per cent.
56's	26	2·6	
54's	7	0·7	
Total	1007		

merino, then approximately eight per cent are strong, of a 60's quality number, twenty-eight per cent are medium with a 64's to 66's quality number, and fifty-five per cent. are fine, and consist of a 70's quality number and finer. Eight per cent are crossbred.

Fibre Fineness and Crimping. Merino wool is bought and sold largely on its fibre fineness and in consequence the estimation of fibre fineness is of major importance to the practical woolman.

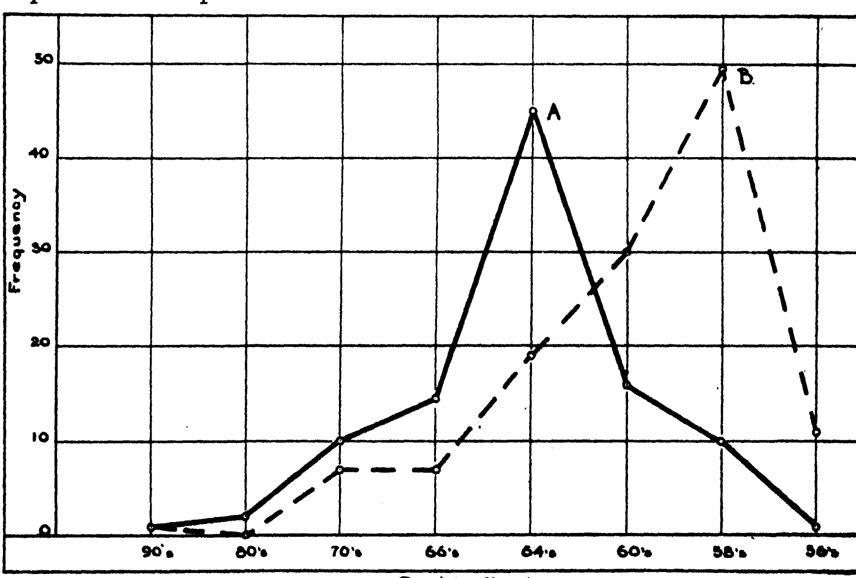


Fig. 9. Graph showing the frequency distributions of quality on crimping and quality on fineness of merino stud ram wool.

Many practical men associate a certain size of crimp with a certain fibre fineness and in practice crimping is used as an aid for determining fineness—the smaller the crimps the finer the fibre, and *vice versa*.

Several workers have investigated the relationship between fibre fineness and crimps. Some have found no significant correlation between the two factors. (Davenpoort and Ritzman (1926) ; Reimers and Swart (1931) ; Hultz and Paschal, (1930)). Others have established a definite relationship. Barker, (1931) gives a summary of workers who found a relationship. Duerden, (1929) established definite standards of crimping and fibre fineness on selected material.

Observations were based on well-grown wool, taken away from skin folds, and the author stated that any droughty grown wool did not necessarily show an agreement between the two factors.

In the present study the relationship between the characteristics of fibre fineness and crimping was investigated and an attempt has been made to define to what extent the relationship is reliable when applied to the South African wool clip. Observations were carried out on 1,000 samples produced in different areas of the Union and the two characteristics are compared on samples which include droughty wools, wools grown in seasons of plenty and wools grown on skin folds. The analysis is based on material as it would pass through the hands of the wool buyer at the coastal ports of the Union and the observations show how far the practical man can form a reliable estimate of fibre fineness when crimping only is considered.

Table XV

The Relationship between Quality Number on Crimps and Quality Number on Fibre Fineness

Qual. No. on crimping / on Fibre fineness	150s	120s	100s	90s	80s	70s	66s	64s	60s	58s	56s	54s
150's	0	—	—	—	—	—	—	3	3	—	—	—
120's	3	3	—	9	—	3	3	—	3	—	—	—
100's	—	—	6	6	3	3	—	—	—	—	—	—
90's	—	9	15	18	24	18	—	—	—	3	—	—
80's	—	—	9	15	48	18	12	9	3	—	—	—
70's	—	—	3	9	27	57	18	42	12	3	3	—
66's	—	—	3	12	15	30	33	24	12	9	—	—
64's	—	—	—	3	9	36	12	45	45	15	6	—
60's	—	—	—	—	—	12	24	21	30	30	6	—
58's	—	—	—	—	6	6	3	3	21	21	15	—
56's	—	—	—	—	—	3	3	—	24	15	18	—
54's	—	—	—	—	—	—	—	—	—	—	9	0

The coefficient of correlation between crimps per inch and fibre fineness is found to be $-0{\cdot}617 \pm 0{\cdot}0226$, which indicates a definite correlation. In general, the more crimps there are per inch, the finer is the fibre.

It is of interest to the practical woolmen to know how far the agreement is of value to him, and a comparison in this respect is made in Table XV, where the relationship between quality number on fibre fineness, and quality number on crimps is shown. The standards for classification used are those of Duerden.

If there were a perfect agreement between the crimping and fineness of wools, the components in Table XV would be grouped diagonally across the table from the top left hand corner to the bottom right hand corner, but these only follow a very general approximation to the ideal agreement. It is shown that only twenty-eight per cent. of the samples lie on the diagonal line and show perfect agreement between the standards of crimps and those of fibre fineness. The rest, or seventy-two per cent. do not follow the perfect agreement but are grouped round it in a general way. Of these, thirty-six per cent. are finer on fineness than the crimps indicate, and thirty-six per cent. are coarser than the crimps indicate.

Of the thirty-six per cent. that are finer than the crimps indicate, seventeen per cent. are coarser by one quality number, twelve per cent. are coarser by

two quality numbers and six per cent. are coarser by more than two quality numbers.

If, therefore, the woolman bases quality number on crimping, he can only form a correct estimate in twenty-eight per cent. of the cases. The chances are even that he can err on the fine side as well as on the coarse side. This applies when a large number of samples is considered. The woolman who bases fineness estimations on crimping on a few samples only, stands a chance of erring considerably. When a large number of estimations is considered, the woolman stands a chance of evening up the errors on the whole.

Crimps are an unreliable guide for the estimation of the fibre fineness of the South African clip as a whole, and this is especially the case where individual samples are concerned. Reliability can only be obtained when the material is selected. The influencing factors of pasturage and environment complicate fineness estimations on merino wool, and for accurate estimations of quality number, fibre fineness should be considered rather than crimping.

B. STUD RAM WOOL

The bulk of the South African clip consists of commercial wool but approximately one to two per cent. is stud ram wool. Since the progeny of stud rams influence commercial flocks, an analysis of stud ram wool has been made. If the wool attributes of stud rams are improved, then an improvement in the wool attributes of the general clip must follow.

In 1931 leading merino breeders in the Union were approached for wool samples from their merino stud sires, and the collection thus obtained, which was used for this study, is representative of stud rams in use in that year. The material is of particular value in that the history of the studs, pedigrees and breeding performances of the sheep concerned, were in most cases supplied, and will serve for future reference when the study is continued on the progeny of the rams.

Wool samples from 123 stud rams were analysed. They consisted of a random selection from 200 samples and include many wools from valuable animals with noteworthy show and sale ring records. The samples were mostly of twelve months' growth and in the form of small staples cut from the shoulder region, wool from skin folds being avoided, since folds influence wool characteristics (see Section IV). Shoulder samples were taken as a basis for comparison as this class of wool forms the largest portion of the fleece and serves as an indication of the bulk of the fleece (Duerden and Bell (1931)).

The samples were fairly uniformly grown, although some showed a variation in crimping and fibre fineness along the staple, presumably due to variations in feed. Some showed the defects often met with in the wool from rams used for service, and known to the practical man as " service breaks."

Crimping was measured in one region of the sample near the skin-end and expressed as number of crimps per unit length.

The frequency distribution of fibre fineness of each sample was obtained, and the mean fineness, standard deviation and coefficient of variability calculated. The sampling for fibre fineness and crimping differed slightly from the usual method employed in analysing wools for commercial purposes. In the latter, a mean of the whole length of the staple is obtained, whilst in the present investigation measurements of crimping, fibre fineness and fibre distribution were confined to one region only in order to eliminate regional differences that might be due to influences of nutrition and service. When the whole length of the staple (where regions vary in fineness) is considered, the fibre distribution is different from that obtained when only one of these regions is studied.

Fibre Fineness and Crimping. In Table XVI is given the fibre fineness, quality number, standard deviation, coefficient of variability, number of crimps per inch, and quality number on crimps. The samples are arranged in order of increasing fibre fineness, and present a range of from $16{\cdot}96\mu$ to $27{\cdot}62\mu$, i.e., from a 90's

quality to a 56's quality which includes practically all the merino qualities, as well as a few coarser ones. A similar result is obtained when the quality number on crimps is compared. The range is from 20-21 per inch (a 90's) to 6-7 per inch (a 56's). The frequencies of the quality numbers on fibre fineness and on crimping in Table XVI are summarised in Table XVII.

Table XVI
Analysis of Fibre Fineness, Crimping Quality Number and the Constants for Variability of Stud Ram Wool

Sample	Fineness in μ	Qual. No. on Fineness	Crimps per inch	Qual. No. on Crimps	Stand. Dev. (in microns)	C. of V. Percent.
29/11	16·95	90's	20—21	90's	2·157	12·7
17/1	18·01	70's	14—15	66's	3·020	16·8
10/2	18·05	,,	12—13	64's	3·675	20·3
21/2	18·18	,,	14—15	66's	3·350	18·4
15/4	18·39	,,	14—15	,,	3·823	20·8
21/1	18·19	,,	14—15	,,	2·518	13·8
23/3	18·50	,,	10—11	60's	2·743	14·8
44/6	18·87	,,	18—19	80's	2·678	14·2
14/1	19·00	66's	12—13	64's	2·883	15·2
17/2	19·18	,,	12—13	,,	3·905	20·4
10/1	19·44	,,	16—17	70's	3·070	15·8
5/3	19·44	,,	14—15	66's	3·390	17·4
3/7	19·54	,,	12—13	64's	3·503	17·9
6/2	19·73	,,	16—17	70's	3·808	19·3
12/1	19·91	,,	16—17	,,	3·418	17·2
2/1	20·03	64's	14—15	66's	3·193	15·9
1/2	20·10	,,	14—15	,,	3·220	16·1
32/1	20·21	,,	12—13	64's	3·018	14·9
7/2	20·34	,,	16—17	70's	3·120	15·3
12/5	20·38	,,	14—15	66's	3·730	18·3
1/3	20·39	,,	14—15	,,	3·260	16·0
16/1	20·59	,,	14—15	,,	2·835	13·8
28/2	20·63	,,	14—15	,,	3·860	18·7
37/2	20·95	,,	14—15	,,	3·053	14·6
19/2	20·95	,,	12—13	64's	3·760	17·9
30/1	20·96	,,	16—17	70's	3·640	17·4
26/1	20·99	,,	16—17	,,	3·970	18·9
39/8	21·05	,,	12—13	64's	3·588	17·0
23/1	21·09	,,	12—13	,,	2·938	13·9
32/2	21·09	64's	14—15	66's	3·455	16·4
39/3	21·14	,,	18—19	80's	3·010	14·2
5/4	21·26	,,	14—15	66's	3·658	17·2
23/4	21·28	,,	14—15	,,	3·435	16·1
18/3	21·32	60's	10—11	60's	3·938	18·5
41/7	21·44	,,	12—13	64's	3·715	17·3
44/7	21·48	,,	16—17	70's	3·985	18·6
19/10	21·53	,,	14—15	66's	2·803	13·0
9/1	21·54	,,	12—13	64's	3·015	14·0
6/1	21·54	,,	10—11	60's	4·235	20·0
39/6	21·55	,,	14—15	66's	4·023	18·7
3/2	21.58	,,	16—17	70's	3·493	16·2
41/1	21·65	,,	12—13	64's	3·563	16·5
10/4	21·70	,,	14—15	66's	3·078	14·2
39/1	21·72	,,	14—15	66's	4·215	19·4
2/4	21·75	,,	10—11	60's	3·255	15·0
10/3	21·75	,,	16—17	70's	3·665	16·9
2/3	21·83	,,	10—11	60's	3·833	17·6
25/5	21·89	,,	12—13	64's	3·355	15·3
19/3	21·90	,,	14—15	66's	3·068	14·0
39/2	21·91	,,	12—13	64's	4·078	18·6
23/2	22·00	,,	8— 9	58's	3·575	16·3
39/5	22·09	,,	8— 9	,,	3·663	16·6
18/4	22·16	,,	10—11	60's	4·140	18·7
19/1	22·22	,,	14—15	66's	3·378	15·2
9/2	22·42	,,	12—13	64's	3·598	16·0
5/2	22·72	,,	14—15	66's	3·795	16·7
4/3	22·72	,,	12—13	64's	4·963	21·8

Table XVI (continued).

Sample	Fineness in μ	Qual. No. on Fineness	Crimps per inch	Qual. No. on Crimps	Stand. Dev. (in microns)	C. of V. Percent.
39/7	22·73	60's	14—15	66's	3·810	16·8
3/1	22·76	,,	12—13	64's	4·318	19·0
24/2	22·80	,,	12—13	,,	4·030	17·7
6/3	22·88	,,	12—13	,,	3·323	14·5
39/4	22·89	,,	10—11	60's	4·583	20·0
1/5	22·91	,,	10—11	,,	4·258	18·6
11/1	23·02	58's	14—15	66's	3·680	16·0
38/1	23·03	,,	10—11	60's	3·490	15·1
34/1	23·08	,,	12—13	64's	3·240	14·1
37/1	23·12	,,	14—15	66's	3·090	13·4
25/2	23·16	,,	14—15	,,	4·257	18·4
35/1	23·18	,,	12—13	64's	3·790	16·4
34/4	23·21	,,	10—11	60's	4·005	17·2
12/4	23·27	,,	12—13	64's	3·452	14·8
34/3	23·41	,,	12—13	,,	4·392	18·8
8/2	23·42	,,	12—13	,,	4·012	17·1
4/1	23·45	,,	14—15	66's	4·027	17·2
24/6	23·47	,,	14—15	,,	3·730	16·0
12/3	23·50	,,	12—13	64's	3·872	16·5
33/3	23·56	,,	8— 9	58's	4·225	17·9
15/2	23·57	,,	14—15	66's	4·252	18·0
23/8	23·58	,,	14—15	,,	4·165	17·7
2/2	23·63	,,	12—13	64's	3·855	16·3
8/3	23·64	,,	8— 9	58's	3·810	16·1
41/3	23·68	,,	12—13	64's	3·820	16·1
41/2	23·78	,,	12—13	64's	3·620	15·2
41/5	23·79	,,	12—13	,,	4·000	16·8
41/4	23·85	,,	8— 9	58's	4·670	19·6
41/6	23·92	,,	8— 9	,,	4·135	17·7
33/4	23·93	,,	10—11	60's	3·770	15·8
5/6	23·98	,,	12—13	64's	4·432	18·5
4/2	23·90	,,	10—11	60's	4·330	18·0
35/7	24·11	,,	10—11	,,	4·117	17·1
3/3	24·16	,,	12—13	64's	4·365	18·1
14/2	24·20	,,	12—13	,,	3·412	14·1
15/3	24·35	,,	14—15	66's	3·527	14·5
15/5	24·36	,,	14—15	66's	3·345	13·7
7/1	24·40	,,	14—15	,,	4·317	17·7
12/2	24·43	,,	12—13	64's	3·578	14·6
18/1	24·51	,,	12—13	,,	4·567	18·6
24/1	24·52	,,	12—13	,,	4·237	17·3
5/5	24·60	,,	14—15	66's	3·885	15·8
3/6	24·60	,,	12—13	64's	4·525	18·4
26/2	24·64	,,	14—15	66's	3·627	14·7
8/1	24·65	,,	12—13	64's	3·557	14·4
39/10	24·66	,,	12—13	,,	3·627	14·7
33/1	24·72	,,	12—13	,,	3·955	16·0
34/5	24·82	,,	10—11	60's	4·370	17·6
40/1	24·91	,,	12—13	64's	4·642	18·6
24/3	24·94	,,	8— 9	58's	3·977	15·9
15/1	25·09	,,	14—15	66's	3·607	14·4
1/4	25·18	,,	8— 9	58's	4·482	17·8
29/1	25·30	,,	14—15	66's	3·745	14·8
25/3	25·41	,,	12—13	64's	3·715	14·6
25/4	25·43	,,	12—13	,,	3·820	15·0
34/2	25·65	56's	12—13	,,	3·907	15·2
20/2	25·65	,,	8— 9	58's	4·995	19·5
44/8	25·65	,,	6— 7	56's	5·160	20·1
39/9	25·68	,,	16—17	70's	4·072	15·9
20/1	25·81	,,	12—13	64's	4·855	18·8
25/1	25·87	,,	12—13	,,	4·355	16·8
28/1	26·26	,,	10—11	60's	4·207	16·0
1/1	27·06	,,	14—15	66's	4·167	15·4
33/2	27·33	,,	8— 9	58's	3·915	14·3
18/2	27·58	,,	12—13	64's	4·970	18·0
33/5	27·62	,,	10—11	60's	5·235	18·9

Table XVII

Stud Ram Wool. An Analysis of the Frequencies of the Quality Numbers on Fibre Fineness and on Crimping

Distribution of Qual. Number on Fineness.				Distribution of Qual. Number on Crimping			
Fineness Range	Qual. Number	Frequency	Per cent.	Crimp Range	Qual. Number	Frequency	Per cent.
16·2-17·0	90's	1	0·8	20-21	90's	1	0·8
17·0-17·9	80's	0	0·0	18-19	80's	2	1·6
17·9-18·9	70's	7	5·7	16-17	70's	10	8·1
18·9-20·0	66's	7	5·7	14-15	66's	38	30·9
20·0-21·3	64's	18	14·6	12-13	64's	45	36·6
21·3-23·0	60's	30	24·4	10-11	60's	16	13·0
23·0-25·5	58's	49	39·8	8- 9	58's	10	8·1
25·5-29·0	56's	11	8·9	6- 7	56's	1	0·8

The assigned quality numbers, based on crimps per inch and fibre fineness, are those established for South African commercial wools (Duerden (1929) ; Duerden and Bosman (1929)), where the authors describe an analysis of greasy wools procured from woolmen, and representative of the quality numbers recognised in wool buying practice.

It is shown that 0·8 per cent. are 90's on crimping ; 1·6 per cent. are 80's ; 8·1 per cent. are 70's ; 30·9 per cent. are 66's ; 36·6 per cent. are 64's ; 13·0 per cent. are 60's ; 8·1 per cent. are 58's and 0·8 per cent. are 56's. From shoulder samples the largest percentage, namely 67·5 per cent. of stud rams in the Union possess a 64/66's, or a medium quality wool on crimping. This method of estimating the quality number of wool is frequently made use of by merino breeders and woolmen.

In Table XVII is also given the frequency distribution of qualities based on fibre fineness. In this case 0·8 per cent. are 90's ; 5·7 per cent. are 70's ; 5·7 per cent. are 66's ; 14·6 per cent. are 64's ; 24·4 per cent. are 60's ; 39·8 per cent. are 58's and 8·9 per cent. are 56's. The largest proportion, i.e., 64.2 per cent. of the Union's stud rams possess a 58's and 60's quality wool on fibre fineness, and for commercial purposes this would be classed as strong wool.

It is thus shown that 67·5 per cent. of stud rams' wools are of a medium quality on crimps, while on fibre fineness 64·2 per cent. are of a strong quality. These facts are expressed graphically in Figure 9 where curve A represents the distribution of the qualities based on crimps and curve B the distribution of qualities on fineness. If there were agreement between the quality number on crimps and that on fibre fineness, the modes of A and B would coincide. However, the mode of A is at 64's and that of B at 58's, indicating that the larger percentage of the samples is 64's on crimping and 58's on fibre fineness.*

A closer analysis of Table XVII is given in Table XVIII where a comparison is made between the relationship of the quality number on crimps and that on fibre fineness. Columns one and two indicate the quality numbers on crimps and on fineness respectively, while in the third column the frequency is given. The fourth column indicates the relationship between quality on fineness and that on crimps.

*The terms "fine", "medium" and "strong" are in general use in South Africa for grading merino wool.

Table XVIII

A Comparison of the Relationships of Quality Number on Crimps and Quality Number on Fineness

Quality on Crimps	Quality on Fineness	Frequency	Quality on Fineness in relation to Quality on Crimps
90's	90's	1	agreement
80's	70's	1	coarser by 1 qual.
,,	64's	1	,, ,, 3 ,,
70's	66's	3	,, ,, 1 ,,
,,	64's	3	,, ,, 2 ,,
,,	60's	3	,, ,, 3 ,,
,,	56's	1	,, ,, 4 ,,
66's	70's	4	finer ,, 1 ,,
,,	66's	1	agreement
,,	64's	10	coarser by 1 qual.
,,	60's	8	,, ,, 2 ,,
,,	58s'	14	,, ,, 3 ,,
,,	56's	1	,, ,, 4 ,,
64's	70's	1	finer ,, 2 ,,
,,	66's	3	,, ,, 1 ,,
,,	64's	4	agreement
,,	60's	10	coarser by 1 qual.
,,	58's	23	,, ,, 2 ,,
,,	56's	4	,, ,, 3 ,,
60's	70's	1	finer by 3 qual.
,,	60's	7	agreement
,,	58's	6	coarser by 1 qual.
,,	56's	2	,, ,, 2 ,,
58's	60's	2	finer by 1 qual.
,,	58's	6	agreement
,,	56's	2	coarser by 1 qual.
56s'	56's	1	agreement

Table XVIII is summarised as follows:—

1 or 0·8 per cent. of samples are finer on thickness than crimps indicate by 3 qual.
1 or 0·8 per cent. ,, ,, ,, ,, 2 ,,
9 or 7·3 per cent. ,, ,, ,, ,, 1 ,,
20 or 16·3 per cent. show agreement between quality on crimps and that on thickness.
32 or 26·0 per cent. of samples are coarser on thickness than crimps indicate by 1 qual.
36 or 29·3 per cent. ,, ,, ,, ,, 2 ,,
22 or 17·9 per cent. ,, ,, ,, ,, 3 ,,
22 or 1·6 per cent. ,, ,, ,, ,, 4 ,,

It is thus seen that: 8·0 per cent. of the samples are finer in fibre fineness than the crimps indicate, 16·3 per cent. show an agreement between quality on fineness and quality on crimps, and 74·8 per cent. are coarser on fibre fineness than the crimps indicate.

C. THE FIBRE VARIABILITY OF SOUTH AFRICAN WOOL

The mean fibre fineness of a sample forms a basis for classifying a wool into its quality number, but the mean does not indicate the degree of fibre variability which is influenced by the number of fineness classes, the range of these and the frequency distribution. From the manufacturer's point of view the degree of fibre variability of wool is a significant factor.

The statistical treatment of fibre measurements has received the attention of various research workers, e.g., Henseler (1926) ; Probst (1926) ; Roberts (1930). Barker (1929), states that " It is not only the average fineness of a sample and its frequency distribution, but also its coefficient of variation within the staple, that is of supreme importance." Expressions of variability, namely standard deviation and coefficient of variability, are useful when fibre variability is studied.

Commercial Wool. The fibre variability of the samples, expressed as coefficient of variability is summarised in Table XIX. The coefficient of variability arranged in class intervals that differ by one per cent., is given, and the frequency and percentage frequency are also shown.

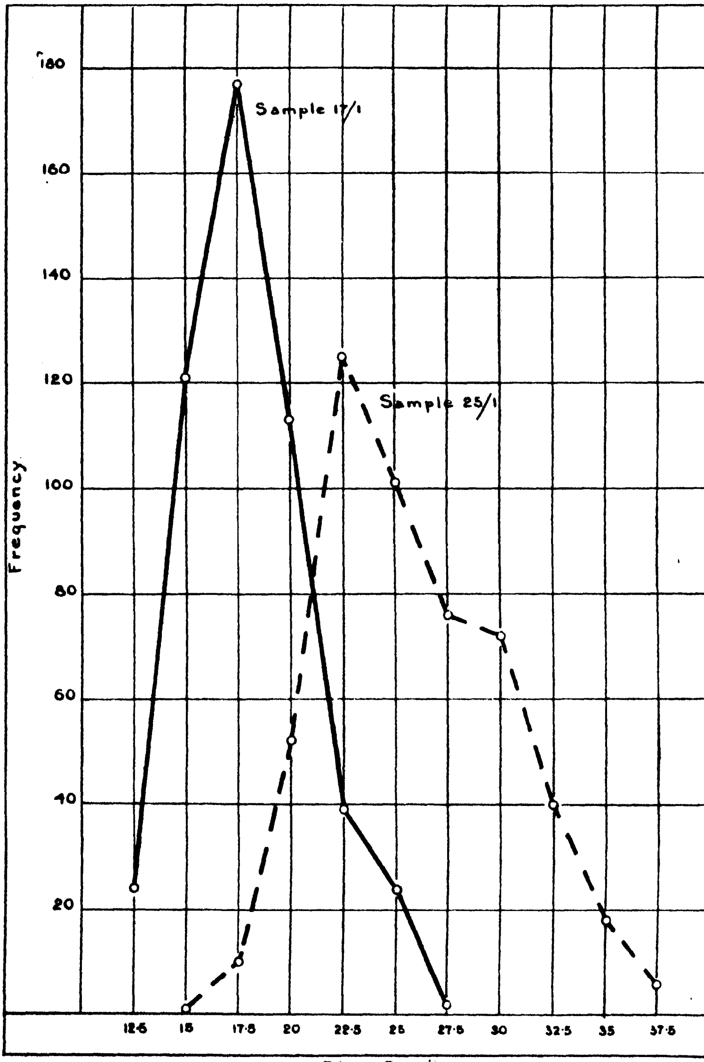


Fig. 10. Graph showing the frequency distribution of fibre fineness of stud rams, Numbers 17/1 and 25/1.

As regards coefficient of variability it is shown that the samples have a range from 10 to 32 per cent. and approximately 79 per cent. range from sixteen to twenty-four per cent. coefficient of variability. Eleven per cent. are more uniform with ten to sixteen per cent. coefficient of variability whilst ten per cent. are more variable with values from 24 to 32 per cent. coefficient of variability.

Stud Ram Wool. The coefficients of fibre variability are given in Table XVI and a summary of the frequencies and percentage frequencies is given in Table XX.

Table XIX
The Frequencies and Percentages of the Coefficients of Variability of One Thousand South African Commercial Samples

Coefficient of variability (Per cent.)	Frequency	Per cent. Frequency	
10—12	5	0·5	10·8
12—14	20	2·0	
14—16	84	8·3	
16—18	179	17·8	79·0
18—20	289	28·7	
20—22	195	19·4	
22—24	132	13·1	
24—26	70	6·9	10·4
26—28	21	2·1	
28—30	7	0·7	
30—32	7	0·7	
Total	1,007		

Table XX
The Frequencies and Percentage Frequencies of the Coefficients of Variability of Stud Ram Wool

Percentage Range of Coefficient of Variability	Frequency	Percentage Frequency
12—14	7	5·7
14—16	37	30·1
16—18	46	37·4
18—20	27	21·9
20— 2	6	4·9

The largest portion of the South African merino stud sires, namely, 89·4 per cent. has shoulder wool which ranges from 14 per cent. to 20 per cent. as regards coefficient of variability. 5·7 per cent. has a lower coefficient of variability, from 12 per cent. to 14 per cent., and is relatively more uniform, while 4·9 per cent. has a higher coefficient of variability, from 20 per cent. to 22 per cent., and is more variable.

In wool studies the standard deviation is a useful constant, since it bears a close relationship to the form or shape of the distribution curve, and expresses in absolute terms the degree of scatter or dispersion of the variates. It also gives an indication of the fibre purity of any one sample, and, roughly three times the standard deviation on either side of the mean will include all the variates. Its utility for comparative purposes however is restricted, and a comparative measure of variation, the coefficient of variability is mostly used for fibre analysis. The constant expresses the standard deviation as a percentage of the mean and is valuable where wools of different means are compared. It was found that the coefficient of variability alone does not indicate the degree of scatter within a sample.

In Table XVI, samples numbered 17/1 and 25/1 have a coefficient of fibre variability of 16·8 per cent., but the standard deviation, indicating the degree of scatter of the variates, shows the values of 3·02 and 4·35 respectively. A similar comparison can be made between samples 26/1 and 33/5 where both have a coefficient of fibre variability of 18·9 per cent. The former however has a standard deviation of 3·97μ and the latter one of 5·32μ. Illustrations of these samples are given graphically in Figures 10 and 11.

Other examples of fineness distribution curves of rams' wools representing extreme types are given in Figure 12.

A is the curve of sample 29/11 and shows a uniform distribution with a low standard deviation of 2·15μ. The mode is at 17·5μ with a frequency of 216, so that 43 per cent. of the fibres measure 17·5μ. The fineness ranges from 12·5μ to 25μ with 6 class intervals, and a mean of 16·96μ, a 90's quality number.

B is the curve of sample 2/1. The standard deviation is 3·19μ. The fibre fineness ranges from 12·5μ to 30μ with 8 class intervals, and the mode is at 20·0μ with a frequency of 180 or 26 per cent. of fibres of 20·0μ. The mean is 20·03μ, a 64's quality number.

C is the curve of sample 18/1, which shows a more variable distribution with a standard deviation of 4·56μ, and a range from 12·5μ to 42·5μ. The mode is at 25·0μ with a frequency of 127 or 25 per cent. of fibres of 25·0μ. The mean is at 24·51μ, a 58's quality number.

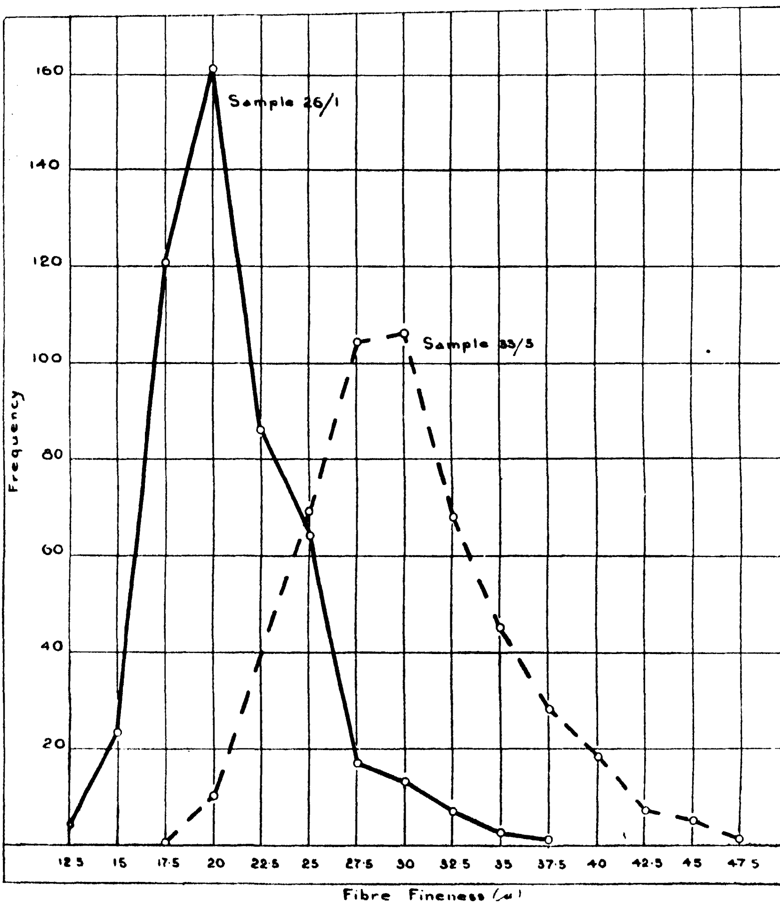


Fig. 11. Graph showing the frequency distribution of the fibre fineness of stud rams, numbers 26/1 and 33/5.

Fibre Variability from a Genetic Aspect. To the textile manufacturer fibre uniformity is a desired wool attribute, and in consequence it is the aim of the sheep breeder to strive for as much uniformity as possible. It is commonly believed that the crossing of fine woolled and coarse woolled types of sheep produces a variable fleece and several authors have described such experiments. Miller (1933), in reviewing publications on the inheritance of wool characteristics, quotes the works of Bailey (1914), who crossed the Merino and Shropshire breeds

of sheep and Pazzini (1915), who crossed the Tiber Valley sheep with Rambouillet rams. Other authors mentioned include Terho (1923) ; Tänzer and Spöttel (1922) ; Hill (1924) ; Davenport and Ritzman (1926) ; Ivanov and Belehov (1928) and others. Most of the workers refer to the crossing of different breeds of sheep. Little has however, been published on the mating of extreme types within the same breed. Several authors, Guthrie (1927) ; Reimers and Swart (1929), have hinted that the marked variability often met with in merino sheep is possibily the result of the mating with a coarse woolled breed. No controlled

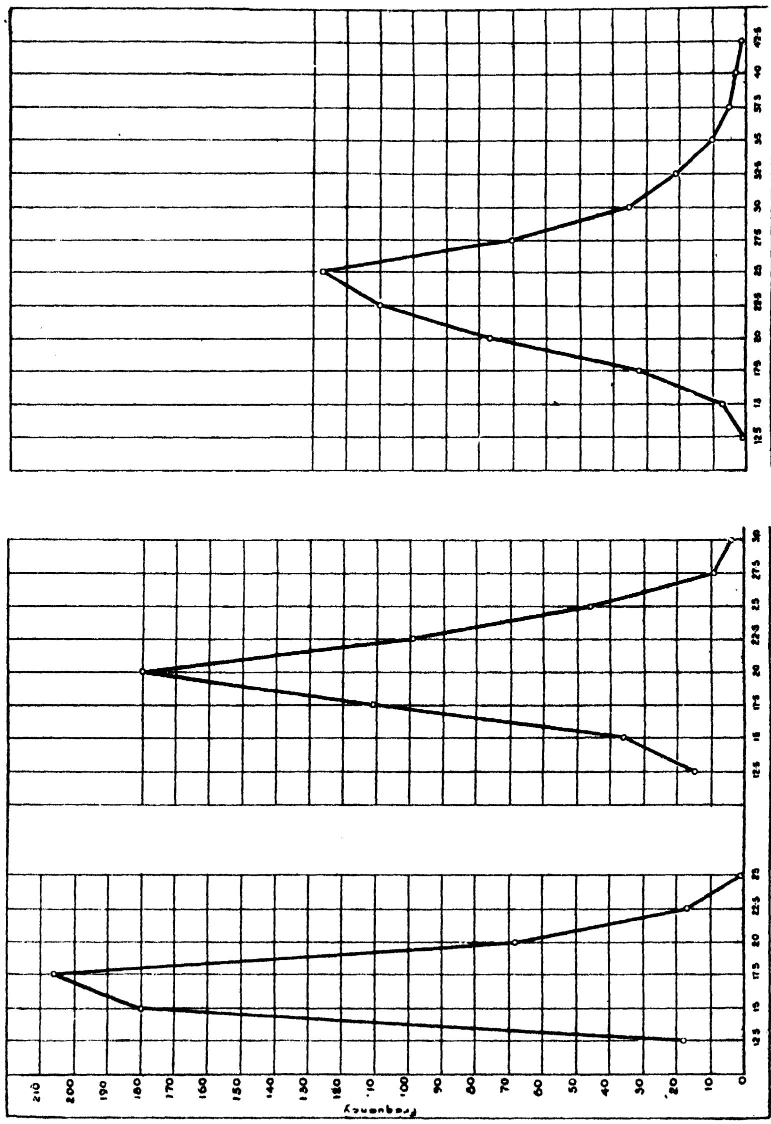


Fig. 12. Graphs showing the frequency distribution of the fibre fineness of Stud rams, Numbers 29/4, 2/1, and 18/1.

merino breeding experiment to demonstrate this has yet been recorded in South Africa and such an experiment is described.

An extremely coarse woolled merino ram was mated to an extremely fine woolled merino ewe. The F1 generation was studied in relation to its parents, and a shoulder wool sample from each of the three sheep was analysed for fibre

fineness and variability. The fibre measurements and constants of fibre variability are summarised in Table XXI and graphically in Figure 13.

The fibre fineness classes differing by 2·5μ are given and the frequencies of the ram, the ewe, and the F1 generation are illustrated.

The mean fibre fineness of the ram was 23·87μ or a 58's quality number and that of the ewe was 15·08μ or a 120's quality number. These two individuals were therefore, extremes as regards fineness. The F1 generation was 22·95μ or a 60's quality number.

As regards variability, the wool of the F1 generation was considerably more variable than that of either the ram or the ewe. The standard deviation and coefficient of variability of the lamb were 5·44μ and 23·74 per cent. respectively, compared with 4·06μ and 17·01 per cent. for the ram and 3·11μ and 20·60 per cent. for the ewe. A graphic representation of the results is given in Figure 13.

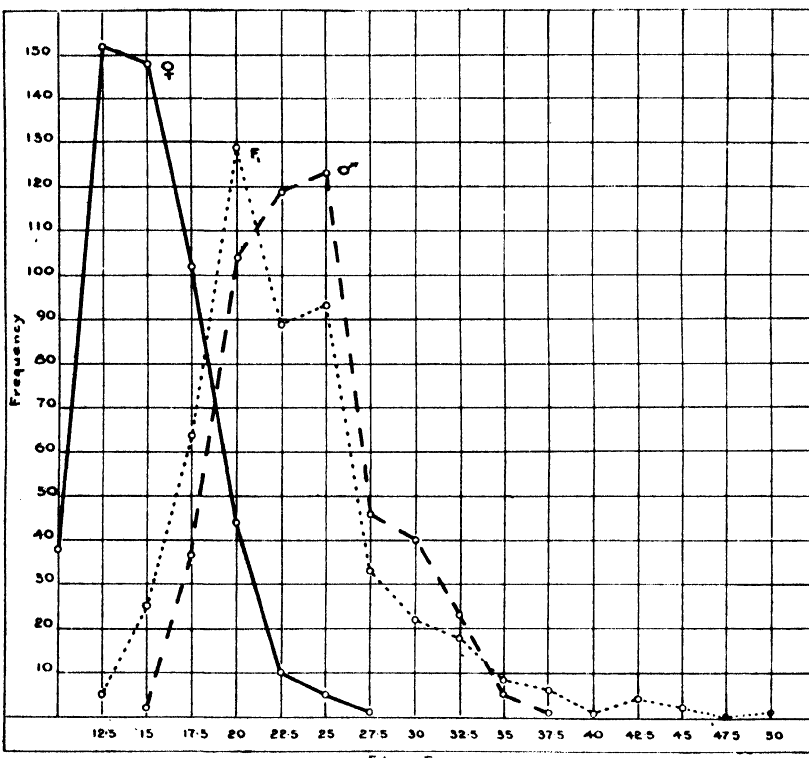


Fig. 13. Graph showing the fibre distribution of the F1 generation and that of the extreme parental types.

In the F1 generation there are a few coarse fibres that do not appear in either of the parents. The results confirm what several authors have found in other breeds and show that the F1 generation has a fineness that is intermediate between the parental types and carries a wool that is markedly more variable in fibre distribution. In the example quoted, the standard deviation of 5·44 shows a larger degree of scatter of the variates round the mean than either the parents which show their values as 4·06 and 3·11 respectively.

The problem has a direct bearing on the breeding of merino sheep and indicates that the mating of extreme types is responsible for an increased fibre variability. It would seem then that the breeder who aims at fibre uniformity

must select for uniformity and mate like to like. Further experiments are in progress where the F2 and F3 generations are studied.

Table XXI
Analysis of the Fibre Distribution of the F1 Generation and the Extreme Parental Types

Fineness Classes (inμ)	Frequencies		
	Ram	Ewe	F1 Generation
10·0	—	38	—
12·5	—	152	5
15·0	2	148	25
17·5	37	102	64
20·0	104	44	129
22·5	119	10	89
25·0	123	5	93
27·5	46	1	33
30·0	40	—	22
32·5	23	—	18
35·0	5	—	8
37·5	1	—	6
40·0	—	—	1
42·5	—	—	4
45·0	—	—	2
47·5	—	—	0
50·0	—	—	1
Totals	500	500	500
Means (μ)	23·87	15·08	22·95
Qual. No.	58's	120's	60's
Stand. Dev. (μ)	4·060	3·108	5·431
C. of V. (Per cent.) ...	17·0	20·6	23·7

Correlation. Definite correlations between wool attributes are useful since, when relationships between characteristics are known, valuable conclusions can often be formed. The coefficients of correlation of the characteristics of the wool of the stud rams are given in Table XXII.

Table XXII
To illustrate the Coefficients of Correlation in Stud Ram Wool

	Fibre Fineness	Crimps per inch	Stand. Dev.	Coeff. of Var.
Fibre Fineness ...	—	− ·426 ± ·0498	+ ·677 ± ·0327	+ ·020 ± ·0608
Crimps per inch...	− ·426 ± ·0498	—	− ·2596 ± ·0567	− ·0218 ± ·061
Stand. Dev. ...	+ ·677 ± ·0327	− ·2596 ± ·0567	—	+ ·0659 ± ·0671
Coeff. of Var. ...	+ ·020 ± ·0608	− ·0218 ± ·061	+ ·0659 ± ·0671	—

Between fibre fineness and crimps per inch the value of −0·426 indicates a definite negative correlation, although not a high one.

As regards fibre fineness and standard deviation the coefficient of correlation of + 0·677 shows a definite positive correlation or, the coarser the wool, the higher the standard deviation.

There is no definite correlation between fibre fineness and coefficient of variability, as the coefficient of correlation of +0·020 indicates.

Likewise, the coefficient of correlation −0·2596 between crimps per inch and standard deviation, indicates no definite relationship. Between the standard deviation and coefficient of variability the value +0·0659 shows no definite correlation.

(*This Paper will be concluded in the September Issue*)

Reviews

Cotton Progress in Brazil. By N. S. Pearse, General Secretary, International Federation of Master Cotton Spinners' and Manufacturers' Associations, 26 Cross Street, Manchester. (pp. xvi + 183. Price, 10/6, post free.)

This volume is the outcome of a brief visit early in 1936 of the General Secretary of the International Federation of Master Cotton Spinners' and Manufacturers' Associations, Mr. N. S. Pearse, to Brazil. The purpose was to observe the progress made in cotton growing since the visits of the three missions sent to Brazil by the International Cotton Federation during the years 1921-1923. Originally a private report of the visit was made to the International Cotton Committee and it was decided that a full report should be published and issued to members.

The general survey which forms the subject of Chapter I, is of great assistance to the reader to whom Brazil is vaguely an extensive part of South America. Since the country has an area not greatly different from that of Europe, and is situated in the tropics and includes all types of land, the great variety of Brazilian products is not surprising.

The sketch of the history of cotton cultivation in Brazil, from the evidence pointing to its great antiquity to the consideration of the statistics of the widely fluctuating exports since 1910, is of considerable interest. While cotton production in the U.S.A. rose from two million pounds in 1791 to 460 million pounds in 1834, Brazilian production remained nearly stationary round about 30 million pounds. Until recently there appears to have been very little systematic effort to develop the production of cotton in Brazil.

Chapters are devoted to climate, varieties of cotton grown, diseases of the cotton plant, Brazilian ginning laws and the organisation developed to prevent mixing of the different kinds of cotton, the classification of crops and the inspection and distribution of seed. Costs of production are considered in detail and from them it is concluded that the Brazilian farmer can grow cotton profitably.

The greater part of the book is devoted to the particular consideration of the various districts in which cotton is grown. In all these a great extension of the cotton industry as a whole is possible. The amount of cotton taken by Brazilian mills is increasing rapidly. T.

Trademark and Monogram Suggestions. By Samuel Welo. Published by Sir Isaac Pitman & Sons, Ltd., London. (Price 10/6.)

The publishers' note on the paper jacket on this volume states:—" This book contains a wealth of material illustrating the fundamentals of an effective trade mark and offering hundreds of detailed practical suggestions. Business executives concerned with sales and advertising will find it a mine of valuable ideas, and commercial artists will welcome it as a rich and stimulating reference book on one of the most absorbing and important branches of their work."

The book is indeed a fine proof that artistry in book production is not entirely a thing of the past. Both author and publisher are to be heartily congratulated, and everyone who deplores the constant loss of real craftsmanship in the hurry of modern life must rejoice to see that such a work can still be produced.

T.

Additions to the Library.

International Cotton Loom Statistics—Census of the World's Cotton Power Looms as on 31st December, 1936. Published by the International Federation of Master Cotton Spinners' and Manufacturers' Associations, 26 Cross Street, Manchester, 2.

Report on Chungteh and Wushung Sheep and Wool. By A. F. Barker, Chiao-Tung University Research Institute, Shanghai, China.

Card Grinding in Theory and Practice. (7th Edition). Compiled and published by Dronsfield Bros. Ltd., Oldham.

Eulan BL, Eulan N, Eulan NK and Eulan NKF Extra. I. G. Farbenindustrie Aktiengesellschaft. (I. G. Dyestuffs Ltd., Bradford).

These leaflets deal with the application of the Eulan mothproofing agents, giving complete instructions for processing.

The Colour Users' Association. Sir H. Sutcliffe Smith's address at the 18th Annual General Meeting, 23rd July, 1937.

Brown Moist-o. Graph. A pamphlet dealing with an instrument for measuring, recording and controlling the moisture content of cotton warp yarns. (Brown Instrument Co., Philadelphia, Pa.)

Solacet Fast Yellow G.S.—Dyeing and Printing recipes. Imperial Chemical Industries Ltd.

"Broadbent" Clutches for Electric Motors. Thomas Broadbent & Sons, Ltd., Huddersfield.

Yorkshire Council for Further Education. Specialised Courses in Advanced Chemistry. 1937-38.

The details of the specialised courses in advanced chemistry to be given in Bradford, Huddersfield, and Leeds during the Session 1937-38 are set out in a very attractive booklet. The need for such courses is dealt with adequately in the short introduction.

The course of 12 lectures under the heading "Further Physical and Chemical Problems in the Textile Industry" cannot possibly fail to be of the greatest interest and help not only to students but to qualified and experienced chemists and technologists. The lecturers are highly qualified specialists who can be relied upon to present the most up-to-date information on their respective subjects.

The course of 10 lectures on "The Theory and Practice of *p*H measurement" to be given by Messrs. W. R. Atkin and F. C. Thompson in the Department of Leather Industries of the University of Leeds should be very welcome to many of the older chemists.

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXVIII SEPTEMBER 1937 No. 9

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

September Meeting of Council

The attendance of this meeting was good and marked the maintained interest members of Council have shown in the business now coming forward for their consideration. The Textiles and Designs Committee reported final adjudication in all Competitions and a list of prize winners has been sent to all Schools and Competitors concerned. The list together with a report of the Prize Distribution on October 9th next will appear in the October issue of the *Journal*. Mr. Frank Pick, Chairman of the Government Council for Art and Industry, will distribute the prizes, and an interesting address by him is anticipated.

The Unification of Testing Methods Committee reported on the completion of the Standardisation Scheme and on its initial distribution to Trade Organisations, Chambers of Commerce, important Firms, etc. A full account of this work now to be undertaken by the Textile Institute in conjunction with the British Standards Institution, and with the Society of Dyers and Colourists appears in this issue on subsequent pages.

An invitation received from the Scottish Section Committee was read. Scottish members suggest that the 1938 Conference should be held in Glasgow and have pointed out that the Empire Exhibition is to be held in that City from May to October next year. A visit to the Exhibition would naturally add to the attractiveness of the Conference. Dr. A. W. Stevenson, Chairman of the Scottish Section Committee was present and urged consideration of the proposal. With the support of the President, Mr. John Crompton, a resolution to hold the Conference of 1938 in the Glasgow area was carried unanimously.

Obituary: Professor J. E. Duerden

With the death, following a fall sustained while attending the recent meetings of the British Association in Nottingham, of Professor J. E. Duerden, the Institute lost a notable member. Professor Duerden, who was 72, was on the staff of the Wool Industries Research Association at Torridon and his work in connection with biological aspects of wool production was well known. He had held zoological appointments in Dublin, Grahamstown, South Africa and in Kingston, Jamaica, conducting researches into a wide variety of biological problems. He belonged to a generation of zoologists whose knowledge of their subject was both wide and deep: a generation that is rapidly passing away and unlikely to be duplicated under modern conditions of study in the subject.

Sectional Activities and Meetings

In the August issue reference was made to the programme of events already fixed-up by the Midlands Section. Other Section Committees have been actively engaged in similar work and it is now possible to deal generally with some of

their plans. The Lancashire Section programme is in print and has been sent out to all members and others interested. Over a hundred have been distributed to non-members in the hope of arousing their interest in the work. The first meeting of the Session was held at the Institute on 22nd September when Mr. N. C. Marples, M.Sc., of Henry Wiggin & Co. Ltd., gave a lecture on "Some High Nickel Alloys—their properties and uses in Textile wet processing." The next meeting is the Annual Prize Distribution on October 9th to which reference has already been made above. The Yorkshire Section commences its Winter Session with a Social Evening on October 7th, when Mr. Otto Mombert will speak. On the same date, as already announced, the first Irish Section meeting will be held. This will take the form of a discussion on the Institute's Standardisation Scheme and the speakers will include Mr. C. Le Maistre, Director of the British Standards Institution, Dr. W. H. Gibson and Mr. Frank Nasmith. The London Section Lecture Sub-Committee met on the 23rd September and has planned some attractive meetings. Details are not yet available but announcement will be made as soon as possible.

Yorkshire Council for Further Education. Specialised Courses for the Textile Industry, 1937-1938.

In the August Issue of the *Journal* reference was made to the Specialised Courses in Advanced Chemistry arranged by the Yorkshire Council for Further Education. The same committee has arranged the following additional courses:—

At the Bradford Technical College:

"Modern Costing for the Bradford Trade and other Textile Problems."

At the Halifax Municipal Technical College:

1. "Costings in Combing and Spinning."
2. "Modern Methods in Yarn and Cloth Testing."

At the Huddersfield Technical College:

1. "The Industrial Application of Textile Research."
2. "Cost Control in Woollen and Worsted Mills."
3. "Industrial Management and Industrial Law."

The folded leaflet giving particulars of these valuable courses states:—"In compiling the syllabuses of these lecture courses, an attempt has been made to forecast the needs of those who are anxious to keep their minds fresh and their methods up to date. In the turmoil of industrial life it is difficult, if not impossible, to keep abreast of the literature that records the rapid advance of research in science and technology and often points the way to economy in the works, better results, and ultimate profit. Lectures such as these by experts who know how to present the salient points in an interesting way will do much in comparatively short time to guide the students to those discoveries and developments that most nearly affect them in their particular circumstances. Furthermore, they offer valuable opportunities for the discussion of practical problems with men who are capable of appreciating the difficulties and of suggesting solutions. It should be observed that the courses are not elementary in character. Generally speaking they will be based on the assumption that those who enter for them will have attained at least the standard of the Full Technological Certificate of the City and Guilds of London Institute or its equivalent."

The Yorkshire Council for Further Education is to be very warmly congratulated on the courses arranged. If these courses do not arouse real enthusiasm, the Council will be justified in assuming that those engaged in the staple industry of the West Riding have no interest at all in their work. The specialist lecturers have been well and carefully chosen and it is impossible to envisage attendance at the lectures without profit both to the executives and to

their employers. The Council, by its invitation of suggestions for courses in future years, is obviously fulfilling its functions in the most worthy fashion.

Inquiries and communications should be addressed to the Colleges at which the lectures will be given, and suggestions for the Council to the Secretary, Yorkshire Council for Further Education, Education Offices, Calverley Street, Leeds, 1.

Employment Register

The following announcements are taken from entries in our Register of members whose services are on offer. Employers may obtain full particulars on application: —

No. 153—Desires position as Textile Technologist or Technical Advisor or Responsible or Managerial post to Private Firm or Public Body. 15 years' experience in Hosiery Trade. 5 years at Public Testing House, and experience in lecturing. Knowledge of Costing, Factory Management, Past Examiner, A.T.I. Fellow of Microscopical Society. Age 34 years. Prepared to go abroad.

No. 167—A.T.I., 43 years of age, desires position as Representative for Textile Machineries, or Accessories; Supervision or Executive work. Full. Tech. Cert. in Cotton Carding and Spinning and sub. processes. Control and Managerial position over long period with Cotton Spinning and Manufacturing concerns. Certified Textile Engineer, etc. Eastern experience. Willing to go abroad.

No. 168—Desires position as Manager or Weaving Manager or Master. City and Guilds Certificate for Cotton Weaving. Seventeen years' experience as Manager and Weaving Manager including all processes from the raw cotton to the finished piece goods. Age 45 years. Prepared to go abroad.

No. 169—B.Sc.Tech., age 23 years, desires position as Assistant Weaving Manager or Technologist. Speaks German and French. Position preferred abroad. Prizes for designing of woven fabrics.

TEXTILE INSTITUTE DIPLOMAS

Elections to Associateship have been completed as follows, since the appearance of the previous list (July issue of this Journal): —

ASSOCIATESHIP

AIREY, Joseph (Blackburn)
ANGUS, Stanley (Bolton)
BARNES, Richard (Estonia)
CHEETHAM, Fred (Milford, Derbyshire)
DURRELL, Stanley James Taylor (by Renfrew
EDMUNDSON, Greenald (Heckmondwike)
FRAME, James (Dundee)
GOOD, Collis Bernard (Nottingham)
GOODDY, John (Derby)
INGHAM, Frank (Paisley)
JONES, Robert (Shipley)
LAW, Harry (Keighley)
LEACH, Edwin (Wolverhampton)
MARSH, Fred (Pudsey)
PENN, William (Coventry)
SCOTT, Ronald Owen (London)
SMITH, Joseph (Bradford)
WEST, John Rishworth (Silsden)
WILLIAMSON, Reginald (Luddendenfoot

Institute Membership.

At the September meeting of Council, the following were elected to Membership of the Institute :—

Ordinary

C. H. Abbott, Meadow Bank, Bridle Street, Soothill, Batley, Yorks. (Joint Foreman, Blending & Yarn Making Depts., Joseph Hoyle & Sons Ltd.).

V. L. Clarke, Sanderson Fabrics, 100 Acres, Uxbridge, Middlesex (Chief Engineer).

E. Coghlan, c/o 26 Victoria Road, Oulton Broad, Lowestoft, Suffolk (Weaving Clerk).

G. N. Gee, "Sylvester," Baldwin Road, Kidderminster (Chemist, Messrs. Brintons Ltd.).

T. A. Goudah, Mid Hadar, Mansourah, Egypt (Textile Student).

W. T. Holt, Netherley, Greenmount Lane, Bolton (Hosiery Manufacturer).

A. P. Ignacio, c/o S. A. Fabrica Votorantim, Rua 15 ne Novembro 47, Caixa Postal 127, S. Paulo, Brazil (President).

A. S. Lall, c/o R. C. Srivastava, Nawabganj, Cawnpore, India (Student).

J. C. Lilly, 59 Beresford Avenue, Coventry (Control Chemist).

E. M. Pollack, 18, Vermont Avenue, White Plains, New York, U.S.A. (Sewing Thread Manufacturer).

T. C. Varley, "Ingthorpe," Broadway, Blackburn (Dyers' Representative).

H. Whitaker, 58, Towneley Street, Burnley.

C. White, 11, Cheapside, New Road, Belper, Derbyshire (Dyer, Improver).

Junior

A. Bramley, 43, Bright Street, Ilkeston, Derbyshire (Dyer's Assistant, Wm. Gibson & Sons, Castle Donington).

E. F. Gow, 26, Victoria Road, Oulton Broad, Lowestoft, Suffolk (Silk Supervisor).

L. A. Smith, 276, Burnley Road, Colne, Lancs. (Cloth Examiner and Tester).

Institute Competitions.

The Textiles and Designs Committee has completed the adjudication of the entries for the 1936/1937 Competitions. Arrangements in regard to the distribution of prizes have been made together with a three-day exhibition of prize-winning entries in the various competitions. Mr. Frank Pick, Chairman of the Government Council for Art and Industry, has kindly consented to distribute the prizes and the date fixed for the event is Saturday, 9th October, the exhibition being open from 2-30 p.m. on Friday, 8th October, to 5 p.m. on Monday, 11th October. A lecture has also been arranged to follow the Prize Distribution at 6-15 p.m. This will be delivered by Mr. W. Turnbull, Jr., of Messrs. Turnbull & Stockdale Ltd., on "Some Aspects of the Relationship of Art to Industry." The List of Awards, together with the Report of the Committee will be given in a later issue of the *Journal*.

UNIFICATION OF TESTING METHODS AND STANDARDISATION IN TEXTILES

Since a previous announcement in the *Journal* that the Council of the Institute had set up a Standing Committee to deal with the Unification of Testing Methods and analogous matters, much progress has been made, an account of which, up to date, it has not been possible to publish. Sanction now having been given for the distribution of the Institute's Standardisation Scheme to the Trade generally it is possible not only to publish the Scheme in full but to give some account of its evolution and the reception so far accorded to it.

The Unification of Testing Methods Committee was, quite early in its work, brought into touch with the work of the American Society for Testing Materials, with that of the German State Standardisation Bureau, with that of the Society of Dyers and Colourists and with that of the British Standards Institution. The first reaction of the Committee was that it would be necessary to ascertain its position in regard to domestic affairs before exploring foreign fields and subsequent considerations have shown this to be the wisest course.

Contact externally was first made with the British Standards Institution and a joint discussion between representatives of that organisation and of the Textile Institute was held in Manchester in January. At that meeting a basis of co-operation was the topic for discussion and as an outcome an Agreement was framed for consideration by the Councils of both bodies. With certain amendments the Agreement in question was ratified by both Councils and is published hereafter for the general information of members. In all the subsequent work by the Unification of Testing Methods Committee, the British Standards Institution (B.S.I.) has given every assistance and the benefit of its long and varied experience in this field of activity.

The next important step was that of making contact with the Society of Dyers and Colourists. The work of this Society in the field of Fastness in relation to textiles is well known and it was regarded as eminently desirable that such work should not only be suitably recognised but pursued in co-operation with all those interests represented in the Textile Institute. Delegates from both organisations met and discussed a basis for this co-operation. As an outcome, an Agreement was drawn up and after suitable amendment ratified by the Councils of both bodies. This document is also reproduced in this issue.

Over the same period, the Committee was evolving a basis or scheme upon which its work might proceed in such a manner as to be under the scrutiny and advice of the various sections of the Textile Trade as a whole. The entire field of Standardisation was carefully explored and it was found possible to group standardisation work into five groups or sections as follows:—

I—Terms and definitions.
II—Methods and Conditions of Testing.
III—Trade Specifications.
IV—Tolerances.
V—Commercial practices.

It was agreed that so far as Sections IV and V are concerned the Institute could not deal with Standardisation therein. In regard to Section III the

scope of the Committee's work was limited to giving advice upon the technical and scientific aspects of Specifications drawn up by public bodies, such as the Services, Hospitals, Railways, Corporations, etc.

Section II, The Unification of Testing Methods, was regarded as the main concern of the Committee and to this field it would most definitely direct its attention.

Section I, Definitions of Terms, is also to be dealt with in so far as such definitions are scientific and technical and arise in connection with the unification of testing methods. Reference is made to this definition of the field of work to be undertaken at a later point in this article.

Having ratified the necessary Agreements and defined its field of work, the next task before the Committee was to devise the machinery for implementing those agreements and for carrying out the work. It had also to be borne in mind that the close co-operation of Trade interests was deemed of the utmost importance. Accordingly a scheme involving the establishment of a Representative Advisory Committee by the Institute Council was drawn up. After appropriate discussion and amendment it was submitted to Council at its July meeting and received unanimous approval. The Unification of Testing Methods Committee was empowered to carry out the work of distribution of the Scheme to the organisations concerned and of arranging for a Press Conference at which due announcement of the Scheme could be made.

The Press Conference was held at the Institute on Friday, 27th August, and was exceptionally well attended. Mr. Frank Nasmith presided and Mr. W. W. L. Lishman and Mr. A. W. Bayes also represented the Institute. Copies of the Scheme and Agreements were issued and questions put by Press representatives were answered. The Institute's thanks may be recorded here to the representatives then present for the excellent results secured and for the punctilious observance that the request that publication should be withheld until 1st September on which date Trade Organisations would receive copies of the Scheme and invitation to appoint members on the Representative Advisory Committee.

The Scheme itself and copies of the Agreements were first distributed to Trade Federations and Associations numbering some two hundred in all. Then followed distribution to Chambers of Commerce, to prominent Industrial concerns, to Government Departments, Research Associations, Learned Societies, Technical Colleges and Textile Societies—a total of nearly five hundred copies being posted.

It is too early as yet to formulate any accurate survey of the response to this invitation to collaborate with the Institute but correspondence, press reports and personal talks have revealed that serious misunderstanding of our proposals seems to have arisen in certain quarters. The Institute wishes it to be clearly understood that its proposals do not include such matters as the standardisation of fabrics (structure or decoration) or articles for wear, furnishing or other purposes. The proposals are intended to protect the textile trade from such forms of standardisation which the Institute considers are not only undesirable but impossible until methods of testing textile materials are put on a unified basis.

In the pamphlet on Standardisation, reprinted below, the Institute clearly defines under three headings the field of work it is undertaking. To avoid further misunderstanding the meanings of these headings is explained.

I.—Definition of Terms. To include unification of expression of results.

The aim here is to get all sections of the textile trade to use the same terms and the same methods of expressing test results. At a later stage it is hoped agreement may be reached with other countries.

II.—Unification of Testing Methods.

This is the most important section of the field of work: its object is to frame unified methods of testing the properties of fibres, yarns and fabrics, which will be acceptable to all sections of the trade. Where agreement is unobtainable and another method of testing is employed, a description of the method is to be specified. Such an achievement will do much to enable parties to settle their disputes satisfactorily, and may even prevent disputes arising.

III.—Advice on Specifications. To give advice on the technical and scientific accuracy of specifications used by public bodies such as Government departments, Municipal authorities, railways, hospitals, etc.

Attention is drawn here to the word " advice." The Institute does not intend drawing up specifications for goods supplied to public bodies, but only to advise on the scientific and technical accuracy of such existing specifications. In this way the Institute will be safe-guarding trade interests in that it will only agree to those technical specifications " which its specially constituted ad hoc Committees " are satisfied come within the bounds of normal commercial practice.

No section of the work defined above will be submitted for recognition as a British Standard until sanctioned by the Representative Advisory Committee which, in its capacity as a representative trade committee, will have power over all such proposals. This Committee is thus a filter which separates the desirable from the undesirable in matters of trade interest. The Institute's scheme thus protects trade interests by undertaking to give its extensive and expert technical advice in a well-defined commercial controlled field of work.

The Council and Unification of Testing Methods Committee now publish the Scheme in full as well as the Agreements with the British Standards Institution and the Society of Dyers and Colourists in the hope that all members of the Institute interested will make such offers of assistance and advice as they think proper. The task to which the Institute has set its hand is without doubt a big one, probably bigger than any yet essayed. It can only be said that the magnitude of the task is not beyond the strength of the Institute as visualised by its founders or as it is in 1937. It cannot be gainsaid that the justification for the existence of any professional body is the measure of its service to the community. In this Scheme, as of course in all its other functions, the Institute can find a wide field of service to the Textile Industries.

STANDARDISATION
TEXTILE INSTITUTE SCHEME

INTRODUCTION

Representation has constantly been made to the COUNCIL of the TEXTILE INSTITUTE that authoritative definition of textile terms and the unification of Textile Testing Methods on a scientific basis would be of very real benefit to all sections of the Textile Industry.

At home and abroad, much attention has been and is being given to definitions, unification of terms, serviceability measurement and many other aspects of the general subject of Standardisation. National and international organisations, bureaux, and testing laboratories have been established in connection with the various campaigns now afoot.

The Institute's Council cannot view with equanamity the many sectional and even ill-considered proposals and schemes in this field. The responsibilities entrusted to the Institute in its Royal Charter were accepted in the conviction that, by the acquisition and application of scientific knowledge, its duty was to safeguard the interests of the Textile Industries.

It is with confidence in its authority and in the belief that the time is particularly opportune that the Textile Institute now publishes its *Standardisation Scheme.*

AUTHORITY FOR THE SCHEME

Before stating the groundwork upon which this Scheme is based the Institute draws attention to the Authority upon which it acts. After due and proper petition to His Majesty's Privy Council, a Royal Charter was awarded to the Textile Institute in March, 1925. Among the clauses of that Charter is one (2j) which reads that one of " the objects for which the said body corporate is hereby constituted " is:—

To constitute an authority for the determination and recognition of technical and trade standards, usages, terms, definitions, and the like for the textile industry.

GROUNDWORK OF THE SCHEME

In the Introduction above, those considerations upon which the Institute proposes to implement the authority vested in it by Royal Charter are stated: that authority has been quoted. It is now necessary to indicate the steps which have led up to the formulation of this Scheme.

A specially-constituted Standing Committee* was established some two years ago and instructed to survey the general field of Standardisation in Textiles and to make appropriate recommendations to Council.

That Committee prepared a standardisation scheme and reported under four principal headings:—

British Standards Institution.—Agreement has been reached with the Institution on the formulation and publication of National Textile Standards. *The position of the British Standards Institution, recognised by H.M. Government and internationally as the authority for the*

*Unification of Testing Methods Committee.

promulgation of British Standards, establishes the importance of this agreement.

Society of Dyers and Colourists.— With this Socitey, also, agreement has been reached upon all questions of procedure in regard to Fastness Standards. *The Society of Dyers and Colourists has for more than half-a-century occupied a position of eminence and authority in its special field of technology and science.*

Representative Advisory Committee.—The Standing Committee recommended that a Representative Advisory Committee, upon which all Textile Trade interests were represented, should be set up by the Council. All standardisation proposals to be submitted to this Committee for advice as to subsequent action. *In due course this Committee, being fully representative of all Textile Trade interests would, with suitable additions, constitute the Textile Divisional Council of the British Standards Institution.*

Field of Work to be Undertaken. —The Standing Committee stated emphatically that precise definition of the field of work to be undertaken was essential, and that there were aspects of Standardisation with which the Institute should not concern itself. *This definition is stated in the Scheme below—paragraph B.*

STANDARDISATION SCHEME

The COUNCIL of the Institute accepted the recommendations and proposed Scheme as presented by its Standing Committee and now publishes the general outline of the Scheme as follows:—

A.—A REPRESENTATIVE ADVISORY COMMITTEE will be set up forthwith to work in conjunction with the UNIFICATION OF TESTING METHODS COMMITTEE, each exercising the functions assigned to it in the ensuing paragraphs.

B.—The mutual function of these two Committees embraces consideration of " Standardisation " under the following exact and descriptive headings:—

I.—Definition of Terms. To include Unification of expression of results.

II.—Unification of Testing Methods.

III.—Advice on Specifications. To give advice on the technical and scientific accuracy of specifications used by public bodies such as Government departments, Municipal authorities, railways, hospitals, etc.

C.—All Standardisation proposals submitted to the Textile Institute shall be referred to the REPRESENTATIVE ADVISORY COMMITTEE upon whose advice subsequent action in respect of such proposals will depend. Power of Veto in regard to proposals not deemed in the best interests of the Textile Industries rests in this Committee.

D.—The UNIFICATION OF TESTING METHODS COMMITTEE will act as the final co-ordinating Technical Committee in all questions involving methods of test or other matters referred to it by the REPRESENTATIVE ADVISORY COMMITTEE.

E.—Tentative Specifications for Standard Methods of Test will be reconsidered by the REPRESENTATIVE ADVISORY COMMITTEE (with any comments or criticism received) and with the observations of the UNIFICATION OF TESTING METHODS COMMITTEE ten months after having been published in *The Journal of the Textile Institute,* and those agreed upon will be submitted to the British Standards Institution for acceptance as British Standards.

F (*a*).—Representation on the Representative Advisory Committee except as indicated in paragraphs G and H below, shall be through Trade Organisations.

(*b*).—Such organisations shall be entitled to 1, 2, or 3 (*maximum*) representatives on the basis of magnitude.

(*c*).—Financial contributions shall be *pro rata* and for the first three years on a sliding scale as under.

		1st year	2nd year	3rd year
Group A	3 representatives	£50	£75	£100
,, B	2 representatives	£35	£52	£70
,, C	1 representative	£20	£30	£40

G (*a*).—Individuals and Firms not in membership of any Trade Organisation may contribute on the basis of £2 2s. per annum without representation on the Representative Advisory Committee.

(*b*).—Such Individuals and/or Firms however may be represented on the Representative Advisory Committee on the basis of one representative for a minimum group of 10 individuals and/or Firms. Larger groups will be accorded representation on the basis laid down in paragraph F (*c*) as follows:—

10-19 Firms as in Group C
20-39 ,, ,, ,, ,, B
40 or more ,, ,, ,, A

(*c*).—Government Departments, Research Associations, Educational establishments, Technical or Scientific, and non-trading organisations will be accorded representation on the Representative Advisory Committee on a basis to be decided by the Institute Council in each case.

(*d*).—Firms or Corporations of sufficient magnitude desiring direct representation on the Representative Advisory Committee to be accorded such representation on a basis to be decided by the Institute Council.

H.—The Textile Institute will be represented on the Representative Advisory Committee by a maximum of six members (including ex-officio members) but of these only three will be empowered to vote at meetings of the Committee.

THE TEXTILE INSTITUTE
MANCHESTER
19th August, 1937

HUGH L. ROBINSON,
General Secretary

Agreement between the British Standards Institution and the Textile Institute.

1. The Textile Institute is recognised as the appropriate organisation to obtain the industrial and scientific co-operation in the unification of test methods for use in the Textile Industries.

2. These methods of testing shall be published in the Journal of the Textile Institute as tentative standards accompanied by a statement to the effect that they will eventually be issued as British Standards.

3. The British Standards Institution will undertake not to publish in British Standards any specifications or methods of test for textile or other materials or things which concern the textile industry unless they have previously been submitted for comment by the Textile Institute and/or published as tentative standards in the Journal of the Textile Institute.

4. The British Standards Institution will refer to the Textile Institute either for preparation or for comment any proposed methods of test for textiles which any British Standards Institution Committee might require in the preparation of the various British Standards Specifications which in any way touch textile materials for industrial purposes.

5. Any request which the British Standards Institution may receive touching matters within the Textile Industry will be submitted to the Textile Institute for their advice both in regard to the practicability of going forward and particularly in connection with any suggestion for a conference of the interests concerned. The British Standards Institution will issue no textile standards against the advice of the Textile Institute.

6. Conferences called by the British Standards Institution to deal with textile matters will be held at the Textile Institute.

7. The basis of co-operation between the British Standards Institution and the Textile Institute shall be that the British Standards Institution is recognised as the national standardising organisation for the issue of industrial standards.

   The British Standards Institution will be prepared to act conjointly with the Textile Institute in matters concerning the preparation of textile standards. The Textile Institute shall be invited to nominate two members who shall be co-opted to the General Council.

6/4/37

Agreement between the Society of Dyers and Colourists and the Textile Institute.

(1) Whereas the Textile Institute is recognised as the appropriate organisation to obtain industrial and scientific co-operation in the unification of test methods for use in the Textile Industry and in such other standardisation and specification matters as are set forth in the agreement between the British Standards Institution and the Textile Institute, the Textile Institute recognises the Society of Dyers and Colourists as the appropriate organisation to deal with questions of Colour Fastness.

The Society will refer to the Textile Institute either for preparation or comment any proposals for methods of test for textiles in relation to Fastness.

(2) These methods, except as provided in paragraph 3—Test Methods in relation to Fastness—shall be published in the Journal of the Textile Institute as provisional standards accompanied by a statement to the effect that they will eventually be issued as British Standards.

(3) In regard to the unification of methods of measurement or testing for Fastness (to all agencies) and their recognition as British Standards, the following special arrangements in collaboration with the Society of Dyers and Colourists shall be and hereby are, agreed upon between the Textile Institute and the Society of Dyers and Colourists:—

(*a*) The methods already established by the Society in regard to Fastness to Light, Washing, and Perspiration shall be (until and unless revised at some future date) accepted by the Textile Institute and submitted to the British Standards Institution for publication as British Standards (with due recognition of origin and under such financial arrangements as may be accepted by the Society) subject to the terms of the already concluded agreement between the Textile Institute and the British Standards Institution.

(*b*) Future work in regard to the Standardisation (including Unification of Test Methods and provisional Standards in relation thereto) of Fastness measurement shall be undertaken by the Textile Institute in collaboration with the Society of Dyers and Colourists in all respects—e.g., personnel of Committees, publication of results and standard methods (except as in (*c*) below) and financial organisation.

(*c*) In regard to all future research reports, records of tests, discussion of results, standard methods of tests, etc., relating to Fastness (both in respect of future work and in respect of the work defined in (*a*) above) full and prior publication shall be made in the Journal of the Society of Dyers and Colourists except only in respect of the ultimately-accepted tentative standards of Tests which may be published in the Journal of the Textile Institute if so desired. In regard to the records of research, discussion of results, etc., described above, an approved summary only shall be published in the Journal of the Textile Institute.

(*d*) In regard to Standardisation outside the field of Fastness measurement it is also agreed that though full and prior publication of research, tests, and tentative standards shall appear in the Journal of the Textile Institute, approved summaries may, if desired, at any and all times be published in the Journal of the Society of Dyers and Colourists. Collaboration in the above work as distinct from that defined in (*a*), (*b*), and (*c*) above, with the Society of Dyers and Colourists shall take place where necessary and practicable.

16/6/37

BIOLOGICAL STUDIES ON SOUTH AFRICAN MERINO WOOL PRODUCTION*

By VICTOR BOSMAN, M.Sc., D.Sc.

Onderstepoort Research Laboratories, Pretoria, South Africa

(*Continued from p. P306*).

IV. THE FLEECES OF MERINO STUD SHEEP

The standard of excellence of merino stud sheep is higher than that of the ordinary flock sheep and for this reason stud breeders supply flock farmers with the progeny of stud sheep for the improvement of the general flocks.

Fleece analyses of stud rams and stud ewes from one of the leading stud farms in the Union are described and comparisons are made between two types of merino sheep, the plain bodied and the developed type.

A. STUD RAMS.

In general practice a stud ram sires at least forty progeny annually, but in cases where controlled mating is practised, rams have sired hundreds of lambs annually. The standard of excellence of the ram is, therefore, of paramount importance for flock improvement, and a study of the fleeces of sixteen stud rams is outlined.

Fleece Analysis. The investigation takes into account fleece weights, in the grease and as scoured, and yield. Wool samples from shoulder regions are studied in regard to weight of wool produced per square inch of skin, staple length, number of fibres grown per square inch, fibre fineness and fleece density. All estimations are based on a full year's growth and the results are summarised in Table XXIII.

As regards greasy fleece weights there is a range of 13·6 pounds to 32·4 pounds with a mean of 23·3 pounds. The scoured fleece weights vary from 5·4 pounds to 12·3 pounds with a mean of 9·98 pounds. The coefficients of variation of the two factors are respectively 20·4 per cent. and 17·6 per cent. These are, however, not significantly different from one another.

The percentage yield varies from 32·7 to 57·0 per cent. with a mean of 43·1 per cent., a standard deviation of $\pm 6 \cdot 087$ per cent. and a coefficient of variation of 14·1 per cent. This large variation in yield is interesting since all the sheep were run on the same farm. From the wool buyer's point of view the variability in yield among the same flock of sheep assumes a practical importance since the sampling error for yield determination can be large.

As regards weight of wool produced per square inch of skin there is a variation of from 1·14 grams to 2·99 grams with a mean of 2·22 grams, a standard deviation of $\pm 0 \cdot 5406$ and a coefficient of variation of 24·4 per cent.

The staple length varies from 2·4 to 4·1 inches with a mean of 3·35 inches, a standard deviation of $\pm 0 \cdot 3812$, and a coefficient of variation of 11·4 per cent.

The number of fibres grown per square inch of skin varies from 29,500 to 52,300 with a mean of 39,400, a standard deviation of ± 5562 and a coefficient of variation of 14·1 per cent.

As regards fibre fineness, there is a variation of from $19 \cdot 38\mu$ to $25 \cdot 79\mu$ or a variation from a 56's to a 66's quality number. The mean is at $22 \cdot 02\mu$ with a standard deviation of $\pm 1 \cdot 743\mu$ and a coefficient of variation of 7·9 per cent. The percentage skin area occupied by wool fibre varies from 1·45 to 2·90 with

* Thesis approved for the degree of Doctor of Science by the University of South Africa.

Table XXIII.
The Fleece Analysis of Sixteen Stud Rams.

No. of Ram.	Fleece Weight in the grease	Scoured Fleece Weight	Percentage Clean Yield	Wool weight (clean dry) per sq. in. of skin (gms.)	Staple Length in inches	No. of Fibres per sq. inch	Fibre Fineness in microns	Quality Number.	Fleece Density as per cent. skin area
1	25·31 lbs.	12·3	48·8	2·1973	3·4	34,000	25·79	56's	2·76
2	24·1 ,,	12·0	49·5	2·8085	3·7	43,000	20·85	64's	2·28
3	31·2 ,,	11·7	37·0	2·1160	3·5	32,600	24·06	58's	2·26
4	20·3 ,,	11·7	57·0	2·9905	4·1	39,100	22·60	60's	2·44
5	32·4 ,,	10·7	32·7	2·6274	3·5	42,000	22·45	60's	2·58
6	24·3 ,,	10·6	44·0	2·1129	3·5	52,300	19·38	66's	2·39
7	22·0 ,,	10·5	47·2	2·7498	3·3	40,400	22·06	60's	2·39
8	29·0 ,,	10·3	35·3	2·2919	3·5	37,800	23·24	58's	2·48
9	23·2 ,,	10·3	45·4	2·3818	3·5	46,400	20·89	64's	2·47
10	20·5 ,,	9·7	47·1	2·0629	3·2	37,700	23·14	58's	2·46
11	24·5 ,,	9·6	40·0	1·8740	3·4	34,800	23·55	58's	2·35
12	23·5 ,,	9·5	40·6	2·6013	3·0	44,800	23·08	58's	2·90
13	21·8 ,,	9·3	42·7	1·1352	2·8	29,500	20·10	64's	1·45
14	20·7 ,,	8·2	39·2	1·8481	3·5	38,200	20·31	64's	1·92
15	17·5 ,,	7·9	43·9	1·9684	3·3	37,200	20·10	64's	1·83
16	13·6 ,,	5·4	39·5	1·7074	2·4	40,800	20·17	64's	2·02
Mean ...	23·37 lbs.	9·98	43·11	2·2171	3·35	39,440	22·02	60's	2·31
Standard Deviation	4·761 lbs.	1·754	6·087	0·5406	0·3812	5,562	1·743	—	0·3598
Coefficient of Variation	20·4%	17·6%	14·1%	24·4%	11·4%	14·1%	7·9%	—	15·6%

a mean of 2·31, a standard deviation of $\pm 0 \cdot 3598$ and a coefficient of variation of 15·6 per cent.

Correlation of Fleece Characteristics. The calculated coefficients of correlation obtained from Table XXIII are shown in Table XXIV. The values of the correlation coefficients for different levels of significance are known (Fisher (1922)). For 16 individuals and a 5 per cent. significance, the value is 0·4973. On this basis several deductions can be made. The greasy weight of the fleece is significantly correlated with scoured fleece weight (+0·6813) with fibre fineness (+0·5239) and the fleece density as per cent. skin area occupied by wool fibre (+0·5830). The factors, yield, weight per square inch, staple length and number of fibres per square inch are insignificantly correlated to greasy weight. The scoured fleece weight, or clean wool produced, bears a significant relation to the greasy weight when the population as a whole is considered, although individuals in the population may show anomalies. For instance, sheep No. 5, with 32·4 pounds of greasy fleece, produces 10·7 pounds of clean wool. Sheep No. 4, with 20·3 pounds of greasy wool, gives 11·7 pounds of clean wool. Sheep No. 8, however, gives only 10·3 pounds of clean wool from 29 pounds of greasy wool compared with sheep No. 2 which produces 12·0 pounds of clean wool from 24·1 pounds of greasy wool.

Although statistically the correlation coefficient between fleece weight and clean wool is significant, the question of practical application needs consideration. From the farmer's point of view the clean scoured fleece is the only portion of fleece that is of monetary value to him, and this being the case scoured fleece weight should be of primary consideration where the standard of excellence of rams is considered.

An attempt has been made to determine to what extent it is practicable to apply to South African studs the significant statistical correlation between greasy fleece weight and scoured fleece weight.

Eight of the highest producers, as regards greasy weight, give a total scoured fleece weight of 867 pounds. When the eight highest clean fleece weights are selected a total of 898 pounds is obtained, a difference of only 31 pounds or 3·6 per cent. It must be remembered that in this study the sixteen stud rams analysed were all the property of one breeder, and that in general, the number of stud rams owned by stud breeders is often considerably less. Since this is the case and in view of the anomalies previously described, it is of greater advantage in smaller studs to select on clean scoured weight rather than on greasy weight.

Statistically, there is no significant correlation between yield and the fleece attributes of greasy weight, scoured weight, weight of wool per square inch of skin, fibre fineness and density.

As regards weight of wool per square inch of skin, there is a significant coefficient of correlation between this factor and scoured weight, staple length and density per cent.

The staple length is also significantly correlated with scoured weight and weight of wool per square inch of skin.

There is no significant correlation between number of fibres per square inch of skin and the characteristics of greasy weight, scoured weight, yield, weight per square inch of skin, staple length, number of fibres per square inch of skin, fibre fineness and density.

Fibre fineness again is correlated with greasy weight, scoured weight and density.

Density is correlated with greasy weight, weight per square inch of skin and with fibre fineness. Density is dependent on the number of fibres per square inch of skin and on fibre fineness and in consequence is largely determined by them.

Table XXIV. Coefficients of Correlation of the Fleece Characteristics of Stud Rams.

	Greasy weight.	Scoured weight.	Per cent. yield.	Weight per sq. in.	Staple length.	No. of fibres per sq. in.	Fibre fineness.	Density per cent.
Greasy weight ...	—	+ 0·6813	- 0·4406	+0·2525	+ 0·4437	- 0·0469	+ 0·5239	+0 ·5830
Scoured weight ...	+ 0·6813	—	+ 0·3512	+ 0·5010	+ 0·7019	+ 0·0066	+ 0·5542	+ 0·5042
Per cent. yield ...	- 0·4406	+ 0·3512	—	+ 0·3158	+ 0·0364	+ 0·0808	+ 0·0308	+ 0·0796
Weight per sq. in. ...	+ 0·2525	+0·5010	+ 0·3158	—	+ 0·5613	+ 0·4064	+ 0·2575	+ 0·6159
Staple length ...	+ 0·4437	+ 0·7019	+ 0·0364	+ 0·5613	—	+ 0·1488	+ 0·2492	+ 0·3339
No. of Fibres per sq. in.	- 0·0469	+ 0·0066	+ 0·0808	+ 0·4064	+ 0·1488	—	- 0·3774	+ 0·4123
Fibre fineness ...	+ 0·5239	+ 0·5542	+ 0·0308	+ 0·2575	+ 0·2492	- 0·3774	—	+ 0·6721
Density per cent.	+ 0·5830	+ 0·5042	+ 0·0796	+ 0·6159	+ 0·3339	+ 0·4123	+ 0·6721	—

B. MERINO STUD EWES.

A fleece analysis of twenty-six high grade merino stud ewes was made. (These animals are part of a breeding experiment in which the progeny are being studied in relation to the parental stock, and it is intended to investigate the fleece and body characteristics of the sheep, from a genetic aspect.) The animals were all two to three year old daughters of the stud ram "505", (Ram No. 8 in the previous section), which was then the leading merino sire at the Grootfontein School of Agriculture, and in consequence are half sisters. All the ewes were run in one flock and received similar treatment. The fleece analyses are summarised in table form where scoured fleece weights, yield, weight of wool produced per unit area of skin on the shoulder regions, number of fibres grown per unit area of skin, fibre fineness, fleece density, fibre length, and straight fibre length are given. In addition, an analysis of the belly wool is made in regard to weight of wool produced per square cm. of skin, number of fibres per square cm. of skin, fibre fineness, fleece density and straight fibre length. All fleece records are based on twelve months' growth, and photographic records of the sheep are given in Figure 14.

While the study demonstrates a method of recording the characteristics of the merino sheep in experimental work and in stud breeding, comparisons regarding the standard of excellence of stud ewes and the coefficients of variation of the characteristics have been made and are summarised in Table XXV.

Fibre Fineness and Variability. The means for the fibre fineness of the shoulder, belly and britch regions of the twenty-six stud ewes are summarised in Table XXVI, where the means for the groups, the quality numbers and constants for variability are also given.

The means for fibre fineness of shoulder and belly regions are not significantly different from one another, their respective fineness being 20·08μ and 21·19μ, a 64's quality number. The britch regions are coarser and measure 23·57μ, a 58's quality number. On the average, the limits of variability in the same fleece, range from a 64's to a 58's quality number.

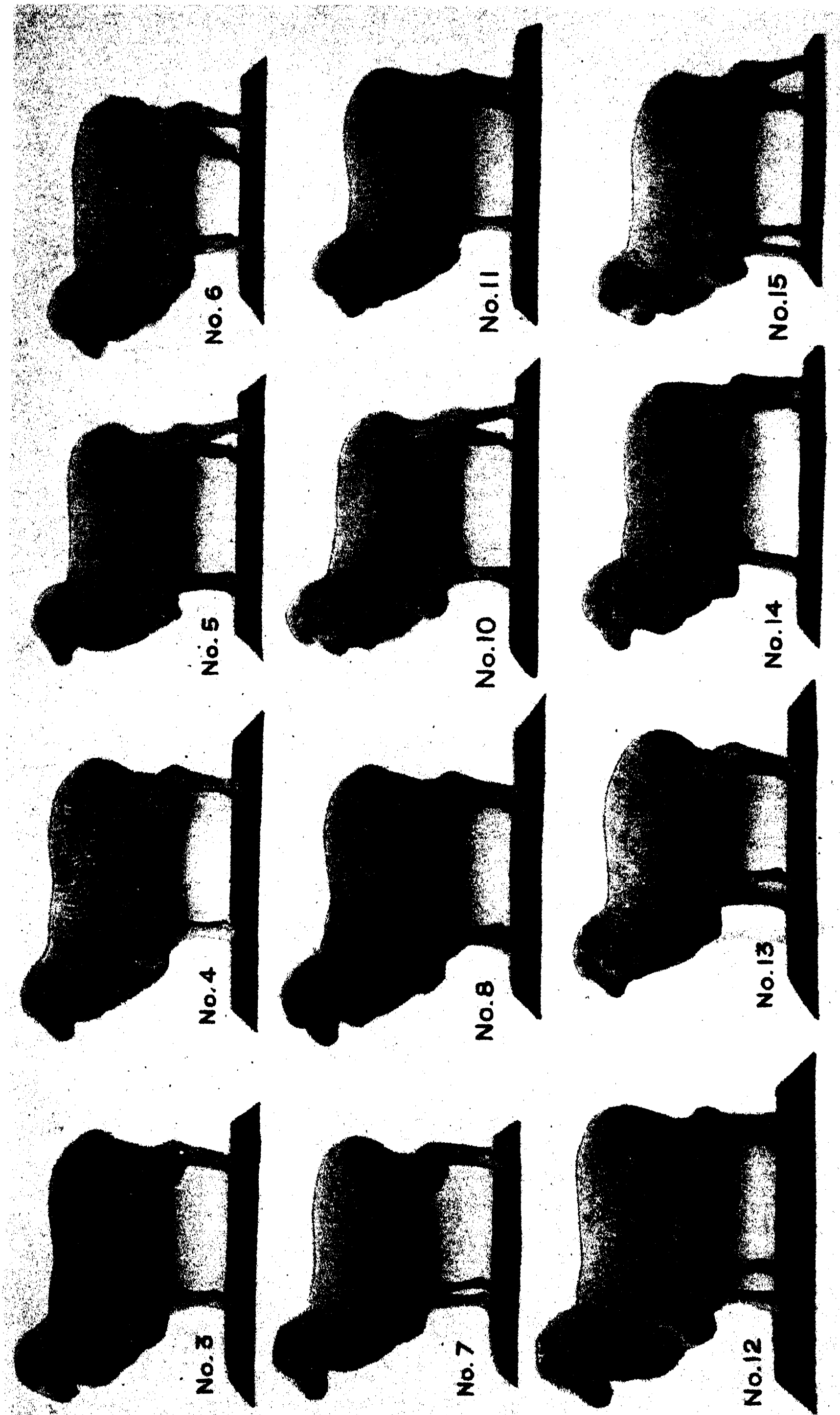


Fig. 14.

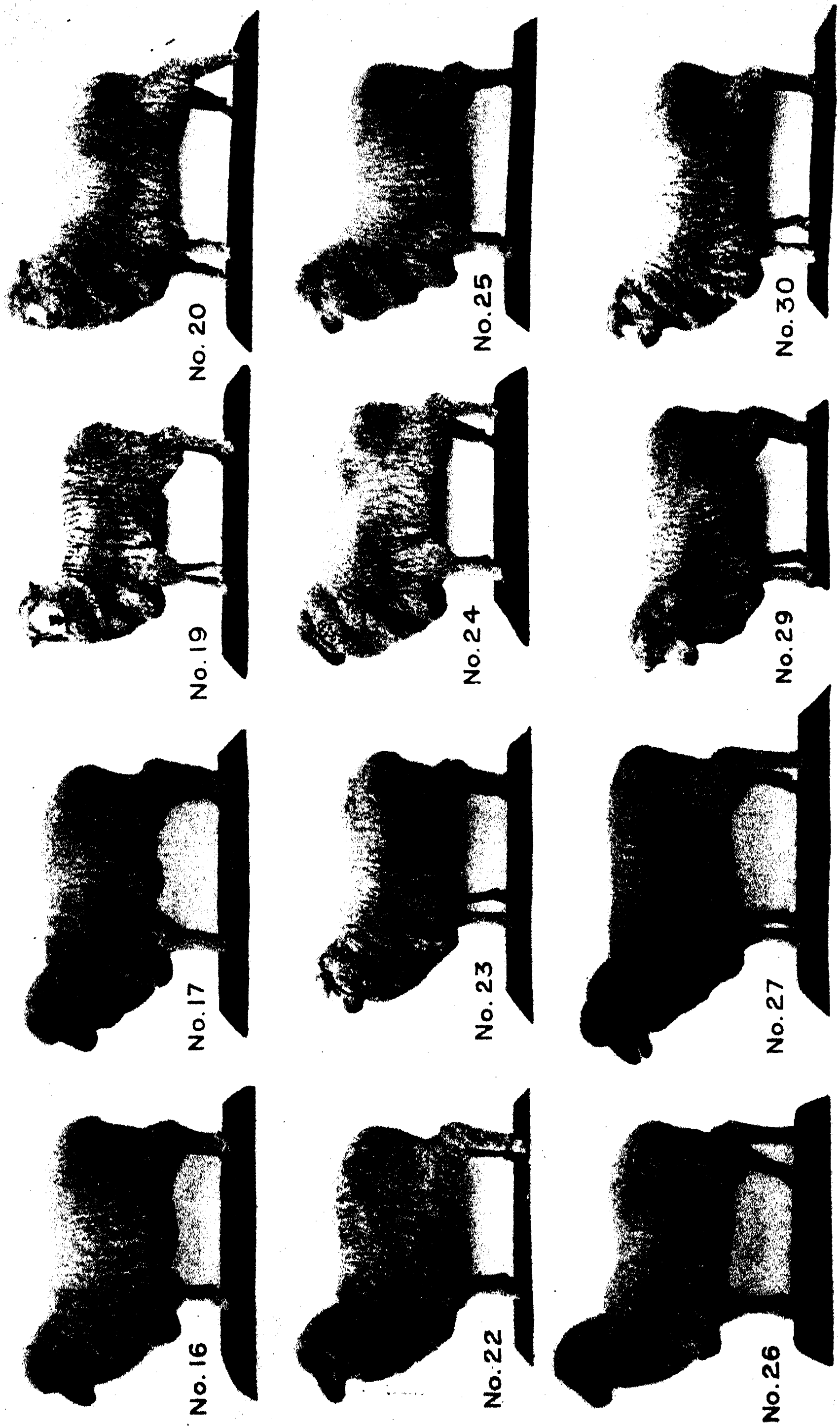

No. 20
No. 19
No. 17
No. 16
No. 25
No. 24
No. 23
No. 22
No. 30
No. 29
No. 27
No. 26

Table XXV. The Fleece Analysis of the Stud Ewes.

No. of Ewe.	Scoured Fleece Weight (grams)	Yield per cent.	Wt. of wool produced clean per 4 sq. cm. Shoulder (grams)	No. of Fibres per sq. cm. Shoulder	Fibre Fineness in μ Shoulder	Fleece Density as % skin area Shoulder	Straight Fibre Length cms. Shoulder	Wt. of wool produced clean per 4 sq. cm. Belly. (grams)	No. of Fibres per sq. cm. of skin Belly	Fibre Fineness in μ Belly	Fleece Density as % skin area Belly	Straight Fibre Length. Cms. Belly
1	4,037	45·4	1·1212	6,509	19·09	1·85	12·75	0·9749	5,272	20·81	1·79	10·45
3	3,513	36·7	1·4560	9,295	18·75	2·64	10·58	0·6611	3,176	21·58	1·16	10·94
4	3,249	49·0	1·5305	8,615	19·64	2·61	11·29	0·8477	3,042	23·00	1·26	12·89
5	2,826	47·9	2·0917	8,990	20·60	2·99	13·43	0·9622	3,570	21·41	1·28	14·40
6	2,950	41·9	1·0839	8,292	17·46	1·94	10·51	1·0194	7,130	17·39	1·69	11·57
7	2,873	48·4	1·4149	6,905	20·60	2·33	11·84	0·7984	3,790	20·84	1·29	11·87
8	3,333	46·0	1·2144	6,110	20·37	1·98	11·72	0·7194	2,790	22·82	1·14	12·12
9	3,158	43·4	1·1390	6,430	19·29	1·89	11·65	0·8407	3,714	21·74	1·38	11·72
10	2,992	50·6	1·8401	9,000	20·76	3·10	11·63	1·0044	5,128	19·97	1·61	12·02
11	2,933	48·4	1·6914	8,327	20·62	2·77	11·71	1·4286	5,861	22·24	2·28	12·06
12	3,245	46·4	1·2731	5,760	21·48	2·15	11·75	0·8573	3,807	21·76	1·42	11·64
13	3,358	49·9	1·1430	6,450	18·95	1·82	12·10	0·4955	2,248	21·81	0·84	11·34
14	2,756	45·0	1·3739	7,435	20·73	2·49	10·54	0·8461	4,012	21·89	1·51	10·77
15	3,144	47·8	1·2806	6,025	21·67	2·22	11·12	0·7949	5,254	18·77	1·45	10·51
16	3,463	45·3	1·2302	5,552	20·91	1·91	12·40	0·7728	3,097	21·69	1·14	12·98
17	3,152	50·9	1·5212	5,750	22·30	2·27	13·02	1·2027	4,150	22·43	1·64	14·10
19	2,910	32·2	1·2224	7,362	20·26	2·36	9·90	1·1282	5,704	21·35	2·04	10·62
20	3,321	51·0	1·0814	6,650	17·09	1·56	13·23	1·0453	4,014	21·76	1·49	13·46
22	3,890	48·6	1·4645	10,607	16·93	2·37	11·79	1·1193	6,800	18·27	1·78	12·07
23	2,868	42·6	1·4606	6,340	21·85	2·42	11·81	0·8155	2,931	24·04	1·33	11·78
24	3,401	41·5	1·4547	7,015	20·73	2·40	11·81	0·6838	3,551	21·74	1·32	9·97
25	3,948	50·2	1·8656	9,370	20·62	3·10	11·46	1·0712	4,871	21·33	1·72	11·83
26	2,867	42·0	0·8627	5,652	19·27	1·64	10·06	0·6369	3,590	21·04	1·25	9·81
27	4,507	53·0	1·4277	5,907	21·25	2·10	13·10	2·0784	8,123	22·11	3·12	12·81
29	3,046	47·1	1·2035	7,000	18·03	1·80	12·95	0·5121	3,171	18·24	0·84	11·88
30	3,664	46·8	1·5233	6,070	22·57	2·44	12·06	0·6246	3,021	21·02	1·05	11·45
Means	3,285	46·1	1·3835	7,208	20·08	2·28	11·78	0·9208	4,301	21·19	1·49	11·82
Standard Deviation	±425·2	± 4·640	±0·2753	±1,405	±1·524	±0·4266	±0·9570	±0·3215	±1,473	±1·543	±0·4928	±1·114
Coefficient of Variation	12·9%	10·1%	19·9%	19·5%	7·57%	18·7%	8·12%	34·9%	34·26%	7·28%	33·01%	9·43%

There is a greater variability than this among individual samples. For instance, sheep No. 6 produces a shoulder wool measuring $17 \cdot 46\mu$, an 80's quality number, and britch wool measuring $21 \cdot 65\mu$, a 60's quality number. Sheep No. 22 produces shoulder wool measuring $16 \cdot 93\mu$, a 90's quality number. It is therefore shown that extreme limits in fibre fineness are obtained from one and the same merino fleece.

As regards the constants for variability, the shoulder regions have a standard deviation of $\pm 1 \cdot 52\mu$ and a coefficient of variation of $7 \cdot 57$ per cent. The belly regions have a standard deviation of $\pm 1 \cdot 54\mu$ and a coefficient of variation of $7 \cdot 28$ per cent. The variability among belly regions is not significantly different from that of the shoulder regions.

The britch regions, with a standard deviation of $\pm 2 \cdot 24\mu$ and a coefficient of variation of $9 \cdot 52$ per cent. are highly significantly more variable than either the shoulder or belly regions.

Table XXVI. The Fibre Fineness and Variability of Shoulder, Belly and Britch Regions of Stud Ewes.

Sheep No.	Fibre Fineness in μ		
	Shoulder	Belly	Britch
1	19·09	20·81	23·52
3	18·75	21·58	23·01
4	19·64	23·00	23·02
5	20·60	21·41	24·93
6	17·46	17·39	21·65
7	20·60	20·84	21·76
8	20·32	22·82	23·98
9	19·29	21·74	24·13
10	20·76	19·97	20·99
11	20·62	22·24	22·37
12	21·48	21·76	25·24
13	18·95	21·81	23·34
14	20·73	21·89	25·35
15	21·67	18·77	29·84
16	20·91	21·69	24·66
17	22·30	22·43	24·06
19	20·26	21·35	25·56
20	17·08	21·76	20·93
22	16·93	18·27	20·10
23	22·15	24·04	26·05
24	20·73	21·74	22·31
25	20·61	21·23	23·08
26	19·27	21·04	23·52
27	21·25	22·11	25·57
29	18·03	18·24	18·72
30	22·57	21·02	25·21
Means (μ)	20·08	21·19	23·57
Qual. Number	64's	64's	58's
Standard Deviation ...	1·52	1·54	2·24
Coefficient of Variation (%) ...	7·57	7·28	9·52

The Fleece Analysis. The scoured fleece weights of the stud ewes range from 2,756 grams to 4,507 grams, or $6 \cdot 1$ pounds to $9 \cdot 9$ pounds, with a mean of 3,285 grams or $7 \cdot 2$ pounds. The standard deviation is $\pm 425 \cdot 2$ grams and the coefficient of variation is $12 \cdot 9$ per cent. This production is almost twice that of the average production per sheep in the Union, which is about seven pounds in the grease. There is considerable variability among individuals, and the highest producer yields $1 \cdot 6$ times that of the lowest.

As regards the yield per cent., there is a variability of from $32 \cdot 2$ per cent. to $53 \cdot 0$ per cent., with a mean of $46 \cdot 1$ per cent. The standard deviation and coefficient of variation are respectively $\pm 4 \cdot 64$ per cent. and $10 \cdot 1$ per cent. It is important to note that an extreme variability for yield occurs in sheep run in the same flock on the same farm. This variation makes the sampling from any one clip extremely difficult.

In the weight of wool produced per 4 square cms. of skin on shoulder regions, there is a variability of from 0·8627 grams to 2·0907 grams, the latter being more than twice the former. The mean is 1·3835 grams with a standard deviation of $\pm$0·2753 grams and a coefficient of variation of 19·9 per cent.

The number of fibres growing on the skin of the shoulder regions varies from 5,552 to 10,607 per square centimetre or from 35,800 to 68,400 per square inch, the latter being almost double the former. The mean is 7,208 per square centimetre or 46,500 per square inch, the standard deviation is $\pm$1,405 per sq. cm. and the coefficient of variation 19·5 per cent.

The fibre fineness on shoulder and belly regions has already been described, but to complete the table of fleece analysis, they are included and are taken into account when correlations are discussed.

The fleece density as per cent. skin area, dependent on the number of fibres per unit area of skin and on fibre fineness, ranges from 1·56 to 3·10 per cent. with a mean of 2·28 per cent. The standard deviation is $\pm$4,266 fibres per unit area and the coefficient of variation is 18·7 per cent. The straight fibre length in the shoulder region varies from 9·90 cms. to 13·43 cms. with a mean of 11·78 cms. a standard deviation of $\pm$0·957 cms., a coefficient of variation of 8·1 per cent. and there is a marked difference of 26·2 per cent. in the rate of fibre growth. These sheep were run in the same flock under the same conditions.

From the manufacturer's point of view length is an important influencing factor in spinning, and since there can be this variation within the same flock it is essential to work towards uniformity in the clip, either by classing the fleeces or by sheep selection.

The weight of wool produced per 4 sq. cm. of skin on the belly regions varies from ·50 grams to 2·08 grams, with a mean of 0·92 grams. The standard deviation is $\pm$0·32 grams and the coefficient of variation is 34·9 per cent. The mean of the belly regions is 33·4 per cent. less than that produced on the shoulder regions. A reduction in belly wool production is shown in every case except in sheep No. 27, which seems anomalous. The diminution of belly wool in relation to shoulder wool is often considerable and in some cases the belly produces less than half the quantity produced on the shoulder.

As regards the number of fibres grown per square centimetre on belly regions, there is a variability of from 2,790 to 8,123 with a mean of 4,301, a standard deviation of $\pm$1,473 and a coefficient of variation of 34·26 per cent. The variability on the belly regions regarding this factor is greater than that on the shoulder regions, the latter having a standard deviation of $\pm$1,405 and a coefficient of variation of 19·5 per cent. The number of fibres per unit area grown on the belly is, therefore, more variable than that on the shoulder.

The fleece density on belly regions varies from 0·84 per cent. to 3·12 per cent. The mean is 1·49 per cent. with a standard deviation of $\pm$0·4928 per cent. and a coefficient of variation of 33·01 per cent. The fleece density is 34·6 per cent. less on the belly than on shoulder regions.

The straight fibre length on belly regions varies from 9·81 to 14·40 cms. with a mean of 11·82 cms., a standard deviation of $\pm$1·114 cms. and a coefficient of variation of 9·43 per cent. Compared with the shoulder regions, there is no significant difference between the means of the two. Neither is there a significant difference between the variabilities of the two regions.

As regards the differences in the constants of variability, the weight of wool produced per unit area on the belly regions is significantly more variable within the group than are the scoured fleece weights within the group. The weights of wool produced per unit area on the belly regions are significantly more variable than those produced on shoulder regions and the number of fibres per unit area on shoulder regions is significantly more variable than that on belly regions.

It is thus shown that belly wool is more variable than shoulder wool regarding the factors of weight of wool per unit area of skin and the number of fibres grown

Table XXVII. The Coefficient of Correlation of Fleece Characteristics of Merino Stud Ewes.

	Scoured Fleece Weight.	Yield.	Wt. of Wool per 4 sq. cm. Shoulder.	No. of Fibres per sq. cm. Shoulder.	Fibre Fineness Shoulder.	Fleece Density Shoulder.	Straight Fibre Length Shoulder.	Wt. of Wool per 4 sq. cm. Belly.	No. of Fibres per sq. cm. Belly.	Fibre Fineness Belly.	Fleece Density Belly.	Straight Fibre Length, Belly.
Scoured Fleece Weight	—	+ ·311	+ ·023	+ ·023	+ ·052	− ·074	+ ·250	+ *·410*	+ 0·351	+ 0·011	+ *0·389*	+ 0·032
Yield	+ ·311	—	+ ·324	− 0·016	+ ·084	− ·073	+ **·660**	+ ·319	+ 0·107	+ 0·006	+ 0·145	**0·568**
Wt. of Wool per 4 sq. cm. (Shoulder)	+ ·023	+ ·324	—	+ **·573**	+ *·402*	+ **·924**	+ ·102	+ ·315	—	—	—	—
No. of Fibres per sq. cm. (Shoulder) ...	+ ·023	− 0·016	+ **·573**	—	− *·410*	+ **·721**	− ·191	+ ·204	+ **0·552**	—	—	—
Fibre Fineness μ (Shoulder) ...	+ ·052	+ ·084	+ *·402*	− *·410*	—	+ *·403*	+ ·054	+ ·115	—	− 0·103	—	—
Fleece Density (Shoulder) ...	− ·074	+ ·073	+ **·924**	+ **·721**	+ *·403*	—	− ·118	+ ·190	—	—	+ 0·178	—
Straight Fibre Length (Shoulder)	+ ·250	+ **·660**	+ ·102	− ·191	+ ·054	− ·118	—	+ ·234	—	—	—	+ **0·672**
Wt. of Wool per 4 sq. cm. (Belly) ...	+ *·410*	+ ·319	+ ·315	+ ·204	·115	·190	·234	—	+ **0·795**	+ 0·096	+ **0·919**	+ 0·368
No. of Fibres per sq. cm. (Belly) ...	+ 0·351	+ 0·107	—	+ **·552**	—	—	—	+ **0·795**	—	− *0·442*	+ **0·873**	+ 0·009
Fibre Fineness (Belly)	+ 0·011	+ 0·006	—	—	+ 0·103	—	—	+ 0·096	− *0·442*	—	+ 0·031	+ 0·216
Fleece Density (Belly)	+ *0·389*	+ 0·145	—	—	—	+ 0·178	—	+ **0·919**	+ **0·873**	+ 0·031	—	+ 0·130
Straight Fibre Length (Belly) ...	+ 0·032	+ **0·568**	—	—	—	—	+ **0·672**	+ 0·368	+ 0·009	+ 0·216	+ 0·130	—

per unit area of skin. This does not apply to the two regions regarding the factors, straight fibre length and fibre fineness.

Correlations. The coefficients of correlation of the fleece characteristics, calculated from Table XXVI are summarised in Table XXVII.

The level of significance of ·39 is based on Fisher's table of significance for 26 individuals. Calculations are omitted where the relationships are not warranted. For example, there is no significant correlation between weight of wool produced per four square cm. on the shoulder and weight of wool produced per 4 square cm. on the belly. Since weight of wool per 4 square cm. on the belly is dependent on the factors, number of fibres per unit area, fibre fineness and fibre length, there is no point in trying to establish a relationship between any of these factors and weight of wool produced per square cm. on the shoulder.

There is no significant correlation between scoured fleece weight and the fleece attributes of yield, weight of wool per 4 square cms., number of fibres per square cm., fibre fineness, fleece density, straight fibre length on shoulder regions, number of fibres per square cm., fibre fineness and straight fibre length on belly regions. (In the previous section on rams' fleece analysis, it was shown that the scoured fleece weight is significantly correlated with weight of wool per unit area of skin (+0·5010), fibre fineness (+·5542), and fleece density (+0·5042) on shoulder regions).

The scoured fleece weight is significantly correlated with the weight of wool produced per 4 square cm. on the belly (+0·410) and with the fleece density on the belly region (+0·389). In general, belly regions are, therefore, an indication of scoured wool production. This is not the case when points on the shoulder regions of the ewes are examined, since there is no significant coefficient of correlation between shoulder wool characteristics and fleece weights.

No significant correlation exists between yield and the fleece characteristics of weight of wool per 4 sq. cms. of skin, number of fibres per sq. cm. and fibre fineness on the shoulder region, fleece density, weight of wool per 4 sq. cm., number of fibres per sq. cm., fibre fineness and fleece density on the belly regions.

Yield is significantly correlated with straight fibre length on the shoulder (+0·660) and straight fibre length on the belly region (+0·568). This means that the higher the yield is, the longer is the fibre on the shoulder and on the belly regions. A longer fibre is thus associated with a cleaner wool.

There is no significant correlation between weight of wool per square cm. on the shoulder and straight fibre length on the shoulder. There is also no significant correlation between weight of wool per 4 sq. cms. on the shoulder and weight of wool per 4 square cms. on the belly.

There is a significant correlation between weight of wool per 4 square cms., number of fibres per 4 square cms. (+0·573), fibre fineness (+0·402) and fleece density (+0·924) on the shoulder region.

There is a significant negative correlation between number of fibres per square cm. on the shoulder and fibre fineness (0·410). This means that the larger the number of fibres per unit area of skin, the finer is the wool. In wool production there is, therefore a tendency towards an inverse relationship in the factors that govern the quantity of wool. The number of fibres per sq. cm. on the shoulder is also correlated with the fleece density on the shoulder (+0·721) and the number of fibres per square cm. on the belly (+0·552). Sheep that show density on the shoulder will in general also show density on the belly.

There is no significant correlation between number of fibres per square cm. on the shoulder, straight fibre length on the shoulder and weight of wool per 4 sq. cm. on the belly.

There is a significant correlation between fibre fineness on the shoulder region and fleece density on the shoulder region (+0·403). The coarser the wool the greater is the fleece density on the shoulder. These relationships, however, do not hold to the same extent when belly wool is considered.

There is no significant correlation between the fibre fineness on shoulder regions and the factors of straight fibre length on the shoulder, weight of wool per 4 sq. cms. on the belly, fibre fineness on the belly and body weights.

There is no significant correlation between fleece density on the shoulder and the factors of straight fibre length, weight of wool per 4 sq. cms. on the belly and fleece density on the belly.

There is a significant correlation between straight fibre length on the shoulder region and straight fibre length on the belly (+0·672) but no significant correlation between straight fibre length on the shoulder and weight of wool per 4 sq. cms. on the belly.

There is a significant correlation between weight of wool per 4 square cms. on the belly and the factors number of fibres per sq. cm. on the belly (+0·795) and fleece density on the belly (0·919).

There is no significant coefficient of correlation between weight of wool per 4 sq. cms. on the belly and the factors fibre fineness on the belly and straight fibre length on the belly.

There is a significant negative correlation between the number of fibres per sq. cm., on the belly and the fibre fineness on the belly (−0·442). This inverse relationship between the two factors also holds on the shoulder region. The number of fibres per sq. cm. on the belly is also significantly correlated with the fleece density on the belly region (+0·873).

There is no significant coefficient of correlation between the number of fibres per sq. cm. on the belly and the straight fibre length on the belly.

There is no significant correlation between fibre fineness on the belly, the fleece density on the belly and straight fibre length on the belly.

There is no significant correlation between the fleece density on the belly and the straight fibre length on the belly.

Comparisons between the Correlations of Stud Rams and Stud Ewes. When comparisons are made between the values for the coefficient of correlation of the stud ram fleeces and the stud ewe fleeces there is a marked agreement, except in the case of scoured fleece weight and the factors of weight per 4 sq. cms. on the shoulder, fibre fineness on the shoulder, and fleece density on the shoulder. In the ewe fleeces there is no significant correlation between these three factors and the scoured fleece weight but in the ram fleeces there is a significant coefficient of correlation between scoured fleece weight and the factors, weight of wool per unit area of skin (+0·5010), the fibre fineness (+0·5542) and fleece density (+0·5042).

The other difference is shown in the case of the relationships between weight of wool per 4 sq. cms. on the shoulder and the factors, number of fibres per square cm. on the shoulder, and fibre fineness. In the ram fleeces there is an insignificant coefficient of correlation between weight of wool per unit area on the shoulder and the factors, number of fibres per unit area (+·4064) and fibre fineness (+0·2575). In the ewe fleeces there is a significant correlation between weight of wool per unit area and number of fibres per unit area (+0·573) and fibre fineness (+0·402). Although in the one case the correlation is significant and in the other insignificant, there is an insignificant difference between the values. It must, therefore, be concluded that the relationship between weight of wool per unit area of the skin on the shoulder and the factors number of fibres per unit area of skin and fibre fineness on the shoulder is not very marked.

C. PLAIN BODIED AND DEVELOPED* MERINO SHEEP.

It is the aim and object of every merino sheep breeder to obtain as great a bulk of wool from his sheep as possible, always of course with due regard to the quality of the fleece and the constitution and conformation of the sheep.

*Among South African and Australian Sheepmen the term "developed" is synonymous with skin folds on the body of the sheep.

At one time the stud type of merino, considered to represent the high wool producers, was characterised by numerous body folds. Breeders contended that bulky fleeces and skin folds were associated and this contention which was responsible for the breeding of the developed type of merino in Australia, South Africa and America, is still influencing merino breeding. The Australian merino

Fig. 15. Sections through the skin of a developed merino sheep.

stud breeders have, in recent years, reverted to the breeding of a plain bodied type and an illuminating account of forty years of sheep breeding in Australia, published in the New Nation Magazine (1935), describes the evolution of sheep types. This is illustrated by the champion rams of the Sydney Show, from the years 1895 to 1934.

The introduction into Australia of the heavily folded Vermont type has been a bitter experience to the Australian flock master, since extremely heavy losses are experienced during droughts. It was found that over-development and inferior constitution were associated, and in consequence this type of sheep was unable to travel long distances to water and to exist on the scanty herbage available in years of drought (Guthrie (1927)).

The American breeders distinguish the types A, B and C representing different grades of fold development. In an account of the history of the merino sheep in America, the Delaine-Merino Record Association (1) asserts that the A type, with numerous body folds, was evolved by the constant selection for high wool production. It is said that " wrinkles " then came not because breeders worked for them, but as a result of working for greater density and weight of fleece. This fact has, however, not been established experimentally, but such data are being obtained from merino breeding experiments at present in progress.

(*a*) *Skin Folds and Fibre Variability*. Skin folds increase the superficial skin area of the sheep and so a larger surface area is available for wool production. If the wool follicles and fibres were uniformly distributed over the whole surface of the skin of a developed sheep, the bulk of wool would be considerably increased by increasing the skin folds. This, however, is not the case, for it has been found that in a developed sheep the distribution of the follicles is not uniform. In certain instances the author has observed that for every five follicles between the folds, there are only three on the folds, so that the producing capacity on the folds is appreciably diminished.

Sections taken at right angles through folds of the skin of a wrinkly merino (Fig. 15), show numerous ridgelike elevations, and the ectoderm appears to be too large for the body of the sheep. A microscopic examination of the wool on the crest of the folds reveals a coarser quality number than that of the wool between the folds. Workers have concluded that skin folds influence fibre fineness (Duerden (1929) ; Reimers and Swart (1929)), and in order to show the extent of this influence in the same fleece, a comparison is made between a series of wool samples that were clipped from the rams " A " and " B," illustrated in Figure 16.

Sheep " A " in Figure 16 is a stud ram representative of a wrinkly merino type. " B " is a plain-bodied animal which in practice would be classed as a " flock " type.

Wool samples were clipped from the crests of folds and from between the folds of " A." The plain-bodied sheep " B," had no skin folds, except for a few small ones on the neck region. The samples from " B " were taken at regions to correspond with those from " A " and the samples from " A " and "B " were analysed in respect of fibre fineness and fibre variability. A summary is given in Table XXVIII.

The means for fibre fineness were obtained by measuring by the camera method, 500 fibres of each sample and the constants for fibre variability, standard deviation and coefficient of variation are given.

Ram " A," the wrinkly animal, had a 54/56's quality on the skin folds, the average fibre fineness for the seven samples being $29 \cdot 87\mu$. Between the folds the wool is finer with an average fineness of $22 \cdot 50\mu$, a 60's quality number.

The samples on the folds of " A " showed a standard deviation ranging from $3 \cdot 75\mu$ to $5 \cdot 10\mu$ and a coefficient of variation of $12 \cdot 2$ per cent. to $18 \cdot 3$ per cent. (The fibre distribution curves are shown in Figure 17). The fold samples showed a greater variability than those from between the folds and had standard deviations of $2 \cdot 63\mu$ to $3 \cdot 60\mu$ and coefficients of variation of $12 \cdot 1$ per cent. to $14 \cdot 4$ per cent.

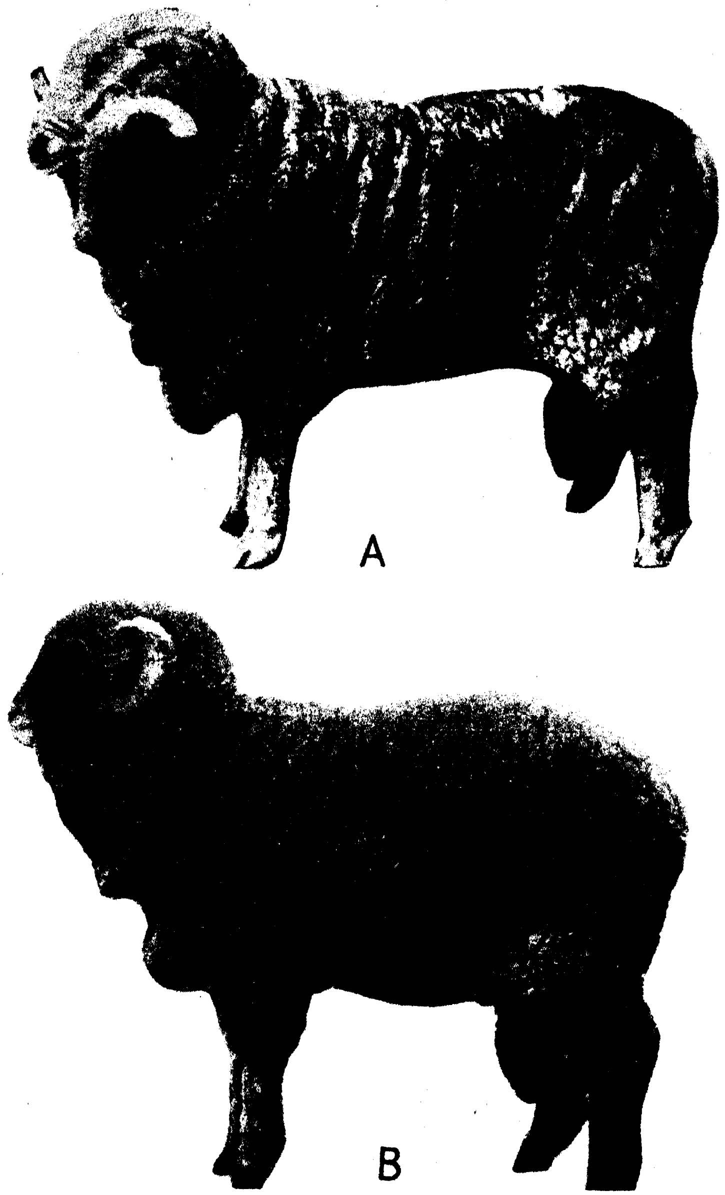


Fig. 16. Developed merino ram (A) and a plain bodied merino ram (B).

Ram "B" had a 64's to a 70's quality wool on the plain body, and eliminating the small neck folds, the average of these samples was $19 \cdot 22\mu$, a 66's quality. The standard deviation ranged from $2 \cdot 37\mu$ to $3 \cdot 37\mu$, and the coefficients of variation from $11 \cdot 2$ to $18 \cdot 4$ per cent.

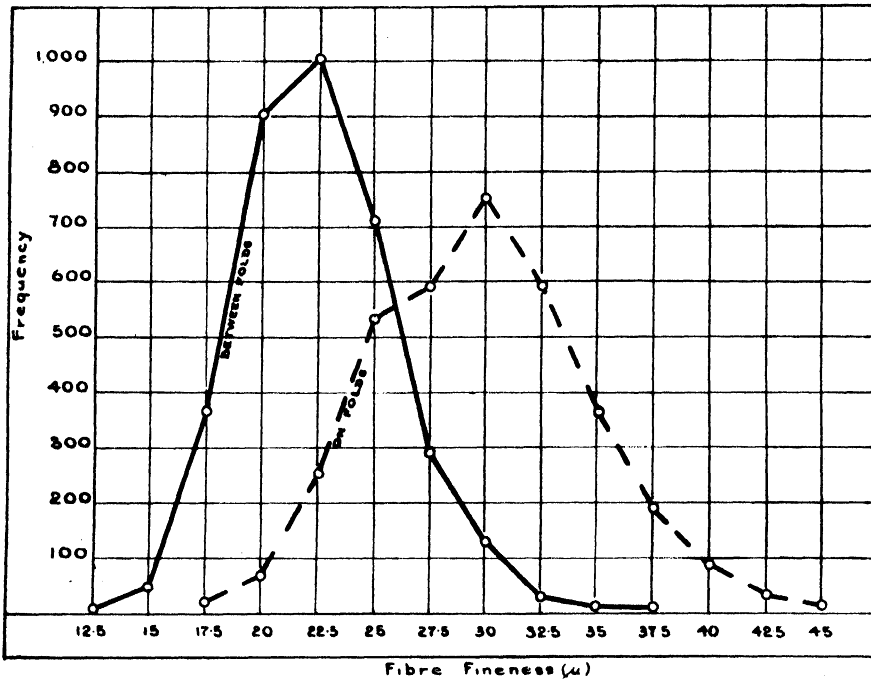


Fig. 17. Frequency distribution of fibre fineness of wool on the skin folds and that between skin folds.

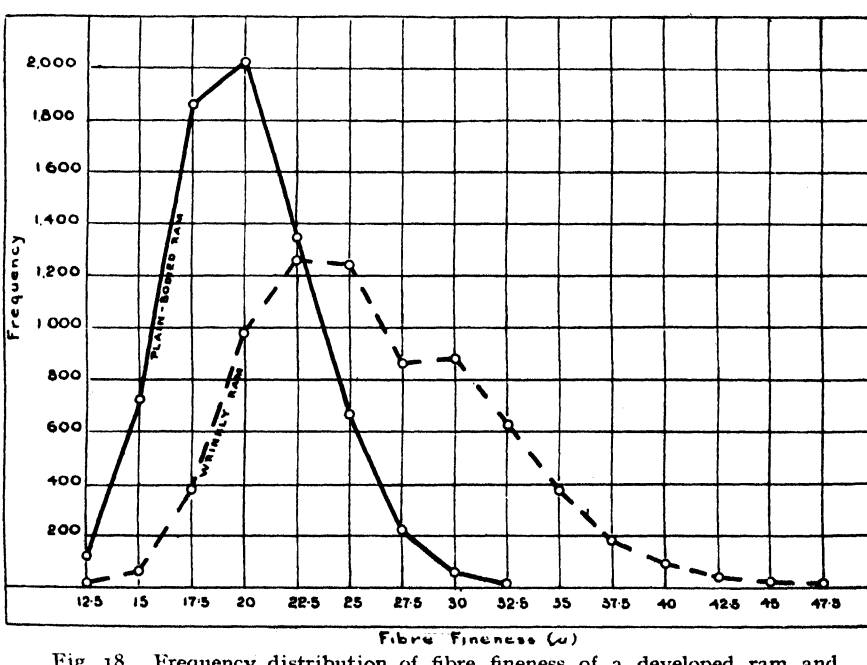


Fig. 18. Frequency distribution of fibre fineness of a developed ram and that of a plain bodied ram.

Table XXVIII. A Comparison of the Fibre Fineness and Variability of Wool taken on and between skin folds.

Regions		Sample	Fibre Thickness in μ	Quality Number	Standard Deviation	Coefficient of Variation
A	On the skin folds	1	39·43	54's	4·65	13·3
		2	28·37	56's	3·77	13·3
		3	26·88	56's	3·75	13·9
		4	30·86	54's	3·77	12·2
		5	30·46	54's	4·37	14·3
		6	29·75	54's	3·85	12·9
		7	27·85	56's	5·10	18·3
		Blend	29·87	54/56's	4·87	16·3
	Between the skin folds	1	25·46	58's	3·60	14·1
		2	21·34	60's	2·75	12·9
		3	21·92	60's	2·90	13·3
		4	20·90	64's	3·02	14·4
		5	20·53	64's	2·62	12·8
		6	24·03	58's	3·07	12·8
		7	23·36	58's	2·82	12·1
		Blend	22·50	60's	3·47	15·4
B		1	21·19	64's	2·37	11·2
		2	22·58	60's	2·87	12·7
		3	20·25	64's	2·67	13·2
		4	21·80	60's	2·95	13·5
		5	20·35	64's	2·97	14·6
		6	18·27	70's	2·80	14·8
		7	18·12	70's	2·75	15·2
		8	18·64	70's	3·25	17·4
		9	18·90	70's	2·95	15·6
		10	18·67	70's	2·52	13·5
		11	18·53	70's	3·20	17·3
		12	18·35	70's	3·37	18·4
		13	19·51	64's	3·07	15·7
		Blend	19·68	64's	3·40	17·0

COMPARISONS OF RAMS (Entire Fleeces)

"A" Wrinkly ...	26·19	56's	5·6	21·4
"B" Plain ...	19·68	64's	3·4	17·0

When all the samples from ram "A," taken on and between the folds, were treated as a blend, and the fleece judged as a whole, the mean fibre fineness of the fourteen samples was 26·19μ, a 56's quality, with a standard deviation of 5·60μ and a coefficient of variation of 21·4 per cent.

A blend of the wool from the plain-bodied ram indicated a more uniform fleece than that from the wrinkly sheep, the standard deviation and coefficient of variation on the plain-bodied animal being respectively $\pm$3·40μ and 17·0 per cent. A comparison between the two types is illustrated in Figure 18 where the fibre distribution curves of rams "A" and "B" are represented graphically.

Fleece Analysis. An analysis of a number of stud rams has revealed that the assertion that quantity of fleece and skin folds are a necessary combination is incorrect. It is shown that the fleece of the plain-bodied type can have the same quantity of wool as the developed type, and when the quality and density of the fleece are compared it is found that the plain-bodied type can produce as fine a quality and as dense a fleece as the merino with body folds.

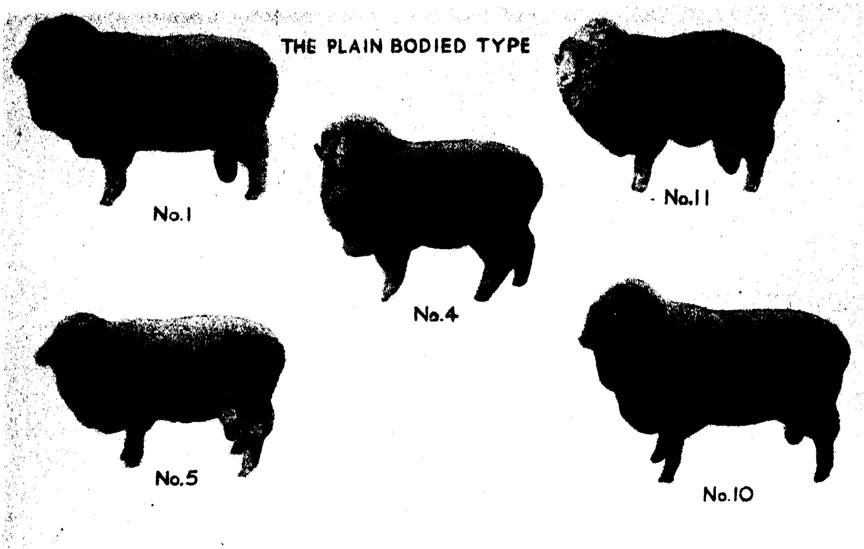


Fig. 19. Group of Plain Bodied Rams.

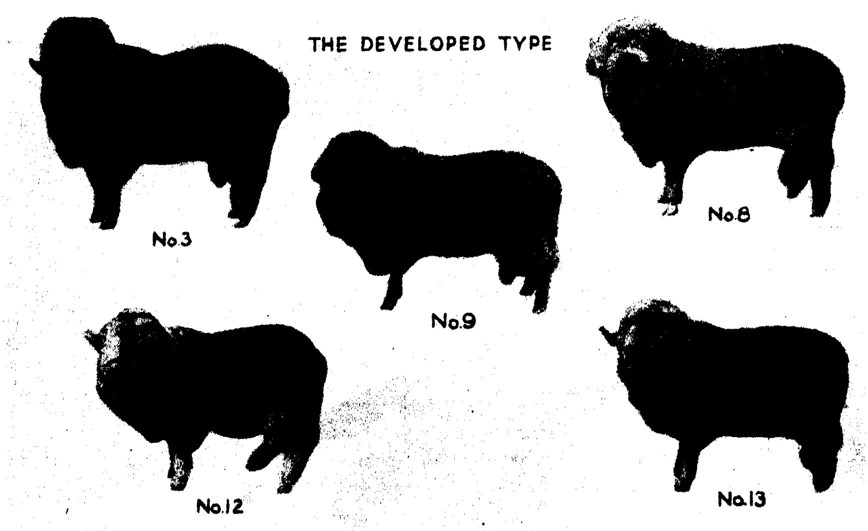


Fig. 20. Group of Developed Rams.

Illustrations of ten stud rams are given in Figures 19 and 20 and the division of the groups is such that two distinct, differing types are represented, one plain and the other with body folds.

In the fleece analysis, the factors of fleece weights, greasy and scoured, yield, number of fibres growing per square inch of skin, fibre fineness, fleece density as per cent. skin area occupied by wool fibre and staple length were considered. The results are summarised in Table XXIX.

The five sheep in the plain-bodied group had scoured weights that ranged from 9·7 to 11·7 pounds. The sheep with skin folds had scoured fleece weights that ranged from 9·3 to 11·7 lbs. The plain-bodied group therefore, produces as much wool as the group with body folds.

As regards the number of fibres growing per square inch of skin, the plain-bodied group produces from 34,000 to 42,000, whilst the developed group produces from 29,500 to 46,400 fibres per square inch of skin. The fleece density as per cent. skin area that is occupied by wool fibre, of the plain-bodied group, ranges from 2·35 per cent. to 2·76 per cent. and the developed group from 1·45 per cent. to 2·90 per cent.

Table XXIX. The Fleece Analysis of Plain-bodied and Developed Merino Stud Rams in regard to Fleece Weights, Yield and Producing Capacity per Unit Area of Skin.

Ram No.	Type	Fleece Weights (lbs.) Greasy	Fleece Weights (lbs.) Scoured	Per cent. Clean Yield	No. of Fibres per sq. in.	Fibre Fineness in microns	Quality No.	Fleece density as % skin area	Staple length in inches
4	Plain bodied ...	20·3	11·7	57·0	39,100	22·60	60's	2·44	4·1
1	,,	25·3	12·3	48·8	34,000	25·79	56's	2·76	3·4
5	,,	32·4	10·7	32·7	42,000	22·45	60's	2·58	3·5
11	,,	24·5	9·6	40·0	34,800	23·55	58's	2·35	3·4
10	,,	20·5	9·7	47·1	37,700	23·14	58's	2·46	3·2
3	With Skin folds	31·2	11·7	37·0	32,600	24·06	58's	2·26	3·5
8	,,	29·0	10·3	35·3	37,800	23·24	58's	2·48	3·5
9	,,	23·2	10·3	45·4	46,400	20·89	64's	2·47	3·5
12	,,	23·5	9·5	40·6	44,800	23·08	58's	2·90	3·0
13	,,	21·8	9·3	42·7	29,500	20·10	64's	1·45	2·8

As regards the standard of excellence of the characteristics of fibre fineness, quality number, and staple length within the two groups, it is shown that as high a standard can be obtained from the plain-bodied group as from the developed type. When quantity and quality of wool are considered, there need be no difference between the fleeces of plain-bodied sheep and those of sheep with body folds. Body folds are, therefore, not necessarily associated with a higher wool production and the conclusions are in agreement with those of Jones and Warwick, (1930) in their work on "Relation of Skin Folds to Weight of Fleece in Rambouillet Sheep". The authors conclude "that the only effect of skin folds is that as the animals get older those with an abundance of skin folds have heavier fleeces, but the fleeces shrink proportionately on scouring, and the heavier-folded animals have a tendency to coarser wool on the thigh than do the smoother bodied animals."

DISCUSSION.

The progress of the South African wool industry is largely due to the efforts of the Department of Agriculture in assisting farmers to class and grade their flocks, and in advising them of improved methods of husbandry.

Further progress will depend to a great extent on improved production which must be aided by scientific research into the fundamentals of production.

In his efforts to improve the standard of production, the wool farmer must take into account environmental and genetic factors, since improvement depends on the constant selection of the right type of individual in the flock, as well as on proper feeding and management of the sheep. At present, successful sheep selection depends on the breeder's aptitude for placing the correct stress on the different fleece characteristics. In practice the sheep judge is guided by hand and eye methods. These empirical methods of observation and selection do not permit of arithmetical expression and in consequence

precise comparisons cannot be made. An experienced sheep judge has developed a natural aptitude for distinguishing the different fleece characteristics, but, since his methods express the factors on a relative basis only, these are often liable to error, and are not suitable where greater precision is necessary. Not only are methods of precision essential in controlled sheep investigations, but such methods are becoming more necessary as an aid to the practical woolman. At the 10th International Wool Conference at Rome (1934) several papers were read in which the authors referred to the measurements of wool attributes, carried out in order to assist the practical man. (Gavazzi (1934); Rausch (1934); Schneider (1934) and others.) Similar papers were read at the 11th International Wool Congress at Berlin (1935). (Rausch (1935).)

The progress made in studies on merino wool production is dependent on the suitability of the methods used for analysing the fleece. Several overseas workers have established methods for analysing fleece characteristics, but in many cases the wool from breeds of sheep other than the merino was used, and it was found that some of the methods that were suitable for the fleeces of coarser woolled sheep, such as the British breeds, were not suited for the merino with its fine, dense fleece. In addition, many workers have analysed wool as a raw product for spinning, apart from its association with the animal. For biological studies on wool production, it is, however, essential that the methods of analysis should be suitable for investigating the fleece as a primary product in its association with the animal.

It has been shown that fibre fineness is an outstanding characteristic of South African wool, and in consequence this attribute has received prominence in the study. Methods for measuring the fibre fineness of wool have been discussed by various workers, and the micro-camera method for measuring fibre fineness which was adopted in the present study has the following advantages:—

1. A thorough sampling of a composite sample, such as a fleece, or number of fleeces, is possible.

2. It is a quick and ready method and the actual measurement of 250 fibres can be completed in about thirty minutes.

3. The mean as well as the degree of fibre variability can be calculated.

With the camera method it was possible to investigate fibre fineness on the extensive scale necessary in a survey of the fineness of South African wool. Measurements established that the South African wool clip ranges in fibre fineness from $7 \cdot 5\mu$ to 50μ with a mean of $19 \cdot 1\mu$—a 66's quality number. This expresses in precise terms the basic characteristic of South African wool.

The study has shown that South Africa produces a remarkably high proportion of superfine wool, from a 90's quality number to a 150's quality number, and since this type of wool is not quoted for separately, by the trade, it is all included in the description of 80's and finer, and no special discriminations are made between the higher quality numbers. If the quality numbers of 90's to 150's are of greater value to the manufacturer, then the wool farmer should be compensated for producing this superfine material.

It must be admitted that the discrimination of the superfine qualities by the ordinary practical methods is extremely difficult. Tests to distinguish the superfine wools in practice have shown that woolmen can err considerably in their estimations, and, where distinctions between the superfine wools are necessary, laboratory methods are a valuable aid.

Manufacturers have expressed a preference for fine wool, but the wool producer contends that economically, the production of fine wool is not a paying proposition. From the merino slide rule it has been shown that to produce a scoured fleece weight of five pounds of an 80's quality number, 40,000 fibres per square inch of skin are necessary, whilst for a 60's quality number with the same fleece weight, only 25,000 fibres per square inch of skin are required. When fleece weight is sacrificed to the production of a wool of a finer quality

number, the former fleece weight can be restored, either by increasing the number of fibres per square inch of skin, or by increasing the fibre length, assuming the total skin area to remain unaltered. In practice, however, it is easier to breed sheep with 25,000 fibres per square inch of skin and a 60's quality number, than it is to breed sheep with 40,000 fibres per square inch of skin and an 80's quality number, and at the same time maintain the fleece weight. Since this is the case, wool farmers will naturally prefer to produce the coarser quality wool unless there is some compensation for the extra efforts involved in the production in conjunction with maintenance of fleece weight of the finer fleeces.

The production of coarse merino wool is not to the advantage of the South African wool producer since this type of wool is in competition with the " comeback " wools of Australia. It is, therefore, evident that the better paying proposition for the South African wool farmer is to breed towards the happy mean and produce a 64/66's quality wool. It is shown that this is the average quality number of the South African clip of which 50 per cent. conforms to a 64/66/70's quality number. The fact that 50 per cent. of the wool is finer and coarser than the 64/66/70's quality number demonstrates the necessity that exists for reducing the large variability of the South African clip.

The study of variability, carried out on stud ram wool, has shown that the constants of variability, standard deviation and coefficient of variation, used separately, do not completely express the variability of the fibres in the sample. The standard deviation denotes in absolute terms the degree of scatter of variates, and gives an indication of the fibre purity of the sample. For comparative purposes where samples of differing means are compared, this constant cannot be used and the standard deviation can, therefore, only be used to compare samples that have the same mean or quality number. The coefficient of variation which expresses the standard deviation as a percentage of the mean is used in statistical work, where the variability of samples, having differing means is compared. This constant alone does not indicate the degree of scatter of the variates and in the analyses of rams' wool it is shown that samples with the same coefficient of variation can have totally different standard deviations. It is felt that an expression embodying both the constants is necessary, and, until such a constant is available, it is suggested that both the standard deviation and the coefficient of variation be employed in studies of the variability of wool.

South African merino wool, in common with all other wools, possesses a fibre variability within the same staple and within the same fleece, but on account of its fibre fineness, it enjoys a keen demand on the world's wool markets, and it also has been found that merino wool is unequalled for blending with fine synthetic fibres. The German Textile material " Wollstra ", which consists of a mixture of vistra and merino wool fibres, contains up to fifty per cent. of pure merino wool in the finished fabric, (Bosman, (1935)). Photo-micrographs and measurements of " Wollstra " yarn show that the " vistra " fibres are made as fine as, and finer than, merino fibres and in consequence the resultant blend is fine and uniform.

In the analysis of the " Wollstra " samples referred to, cross-sections of the yarn showed a marked uniformity among vistra fibres (the manufacturer of synthetic fibres depends on mechanised processes of production and any desired uniformity is possible) but a lack of this among merino fibres. Fibre uniformity is partly a genetic factor, and improvement in this attribute is largely controlled by selection in breeding practice. Selection for uniformity in fibre fineness in the same staple will also tend to produce uniformity in fibre length, since there is an almost perfect correlation between these two factors (Duerden and Bosman (1931)).

Miller (1933) in discussing the inheritance of wool characters in sheep, points out " that where only one wool character has been studied, the bulk of the evidence shows that with few exceptions the character in question is exhibited by the progeny to a degree which is intermediate between the parental types." This also appears to be the case in the merino and is illustrated in the crossing of an extreme fine woolled with an extreme coarse woolled sheep. Apart from the intermediate fineness of the progeny, there was a marked lack of uniformity exhibited to a much greater degree than was the case with the parent generation. This indicates the importance of sheep selection in breeding practice, especially when fibre uniformity is the ultimate ideal. Barker states that " if the doctrine of uniformity of the fibre be made the text of the producer, then the future of the wool industries is more likely to be assured." Although the attainment of perfect uniformity in merino wool may be impossible, yet the average can be improved by selection, since it has been shown that there are individuals that are considerably more uniform than others.

The responsibility for the future of the wool industry lies with the wool producer, who produces wool as raw material for the manufacturer. The basic characteristics of the finished product are largely dependent on the basic characteristics of the raw material and these in turn are largely influenced by selection in breeding, prior to the producing stage. Recently, when the production of wool was unprofitable*, the South African sheep farmer turned towards the potentialities of mutton and fat lamb production, and cross-breeding experiments were undertaken.

South Africa is, however, primarily a wool producing country, and while cross-breeding may serve a useful purpose, from a mutton point of view, the purity of the merino wool clip must not be endangered. It has taken years of constant care and selection in breeding to arrive at the present standard of production, and the maintenance and improvement of this standard should be the first consideration of the wool producer. With the increased competition of synthetic fibres on the world's markets, the desirable characteristics of merino wool should be exploited to the fullest possible extent and it is, therefore, of supreme importance that the excellence of South African wool should not be sacrificed.

It has been said that the improvement in South African wool production is due to Australian sheep, and there is a certain amount of truth in this assertion since most of the South African merino studs were founded on importations from Australia. In his address to the Historical Society of Victoria, Senator Guthrie (1927) asserted that " as a result of the free introduction of high class Australian merino sheep, South Africa is now Australia's greatest and practically only competitor in the production of merino wool ". Since the embargo on the importation of stud merinos from Australia continues, the South African breeder must develop on his own lines. The application of the results of research into the standards of excellence of the merino based on arithmetical expressions, such as are described in the present study, would be of immense value in defining any improvements or degeneration in the standard of excellence of the South African merino sheep of the future.

Stud rams constitute only a minute percentage of the South African merino population, but their importance cannot be over-estimated, since it is the progeny of rams that are used for the improvement of the general flocks.

---

* According to the Statistical Wool and Mohair Bulletin of the South African Department of Agriculture (1935), the average selling price of greasy wool, during the seasons 1930 to 1933, was in the vicinity of five pence per pound. Although definite figures concerning the production costs of South African wool are not available, it is definitely asserted that the cost of production was considerably higher than the market price. Figures compiled by the Commonwealth Wool Inquiry Committee of Australia (1932) showed that Australian wool production costs were about fourteen pence per pound. Pastoralists had therefore been producing at a loss. The wool prices of to-day, however, where wool is selling at prices up to sixteen pence per pound, show a margin of profit in production.

It has been shown that stud ram wool is different from all other wool. On crimping, 67·5 per cent. of the wools are 64/66's or a medium quality and in the South African show and sale ring this type would be entered in the medium woolled classes. On fibre fineness, however, 64·2 per cent. are found to have a 58/60's quality or a coarse merino quality number. It is, therefore, evident that the majority of rams entered in the medium woolled classes at shows and sales should in reality be entered in the strong woolled classes. Ram wool needs standards of its own since the fibre fineness is approximately two quality numbers coarser than is indicated by the crimping. Since ram wool is, in three cases out of four, coarser in fineness than the crimps indicate, there is every justification for advising wool farmers to class and sell stud ram wool separately from the general wool clip.

The stud rams concerned in the study, were, from the owner's point of view, valuable animals, and it was suggested that their fineness was coarser than the crimping indicated, on account of their better feeding and care. This criticism was investigated and comparisons made with a group of well-fed experimental flock sheep at the Grootfontein School of Agriculture. It was found that the wool from the latter showed agreement between the quality number on crimps and that on fineness, similar to that described in the analysis of commercial flock wool.

The standards used for classifying the 1,000 commercial wool samples into fineness and crimping were those established by Duerden who used selected material that was well-grown and taken away from skin folds. Seventy-five per cent. of his samples showed a close agreement between fineness and crimping but in the present study only 28 per cent. of the samples showed a perfect agreement between the standards of crimping and fineness, whilst 36 per cent. were finer in fineness than the crimps indicated, and 36 per cent. were coarser in fineness than the crimps indicated. The smaller proportion of agreements in the 1,000 samples was presumably due to the fact that these wools included droughty wools, and wool from skin folds. The fact that there were as many cases below as above the agreement line, is supporting evidence for the justification of using the standards established by Duerden.

Fleece density is one of the main distinguishing features between stud merinos and flock merinos and the estimation of this factor has therefore assumed considerable importance. In South Africa and America the relative merits of show sheep largely depend on the fleece density of the animals. Unfortunately, no such data on Australian show sheep are available. Hultz and Pashal (1930) in their analyses of Rambouillet show sheep, at the International Livestock Exposition in America during the years 1927, 1928 and 1929, concluded that density, as number of fibres per unit area of skin, was more closely associated with show awards than was any of the other characteristics.

In the present study the standard of excellence of the South African merino sheep regarding the factor number of fibres growing per square inch of skin, has been demonstrated, and it is shown that outstanding stud sheep can produce up to 60,000 fibres per square inch of skin, whilst an average stud sheep produces from 30,000 to 40,000 fibres per square inch of skin.

The exceptionally small figure obtained for fleece density when expressed as the percentage skin area occupied by wool fibre, from 1·5 per cent. to 3 per cent. demonstrates that 97 per cent. of the merino skin bears no wool. The compact feeling of the dense merino fleece is due to the impurities of the fleece such as grease, suint and sand and is aided by the springy feel of the wool with its enclosed air. Since the densest merino sheep has only about 3 per cent. of wool fibre, the accuracy of the practical methods for determining the fleece density must be regarded as questionable.

Several overseas research workers have published figures for the factor, number of fibres growing per square inch of skin, and it is interesting to compare

those with the results obtained on the South African merino. A summary is given in Table XXX.

Table XXX. A Comparison of the Results published by different authors on the number of fibres grown per unit area of skin.

Author	Description of Sheep	Regions sampled	No. of Fibres per sq. in.	No. of Sheep analysed
Burns (1933) ...	Stud Rambouillet (American)	Shoulder, back...	24,592	—
Burns (1933) ...	Ramb. × Hampshire cross (f 1)	Side, belly ...	16,012	—
Burns (1933) ...	Ramb. × Hampshire cross (f 2)	Hip, britch ...	14,944	—
Burns (1933) ...	Hampshire	Thigh	9,016	—
Burns (1933) ...	Merino Rams (Australian)	Shoulder, thigh	56,460	2
Burns (1929) ...	Ramb. Show Rams (American)	Shoulder, thigh	30,032	4
Hultz and Paschal (1930)	Ramb. Show Rams (American)	Shoulder, thigh	25,556	101
Hultz and Paschal (1930)	Ramb. Show Ewes (American)	Shoulder, thigh	23,667	
Bosman (Unpublished)	Merino Show Rams... ...	Shoulder ...	45,200	2
Bosman, Section IVA	Merino Stud Rams	Shoulder ...	39,440	16
Bosman, Section IVB	Merino Stud Ewes	Shoulder, belly	37,350	26
Bosman (Unpublished)	Reserve Champion Colesberg Sheep Show, 1934.	Shoulder ... Belly	53,600 27,300	1
Bosman (Unpublished)	Stud Rams from one Merino breeder	Shoulder ...	52,300	4
Bosman (Unpublished)	Flock Ewes	Shoulder ...	20,300	23
Bosman (Unpublished)	Flock wethers	Shoulder ...	19,850	15

The figures show that the American Rambouillet stud sheep has fewer fibres growing per square inch of skin than either the South African or Australian merino. It is interesting to compare the decrease in the number of fibres per unit area of skin in crosses of the Rambouillet with the Hampshire sheep, and also to compare the pure Hampshire with that of the merino. The determinations on the Australian sheep were made on two sheep only, but these animals indicate a high standard of excellence. The standard of excellence of South Africa's best merinos regarding the number of fibres grown per square inch of skin, ranges from 39,440 to 53,600 on shoulder regions. Flock sheep have considerably less, with an average of about 20,000.

In the comparison of plain-bodied and developed merino sheep, it has been shown that where bulk of fleece is concerned, the same standard of excellence can be obtained from the plain-bodied type as from the developed type. The fleece can be equal as regards scoured weight, and the number of fibres grown per square inch of skin. It is, therefore, shown that any preference for the developed type of merino, on the grounds of high wool production, is not justified. It is also evident that the old classification " stud type ", signifying the developed merino, and " flock type " indicating the plain-bodied merino, should be abolished. The same standard of excellence that is found in developed sheep can also be found in the fleeces of the plain-bodied animals and the plain-bodied type should, therefore, be regarded as a stud animal when the standard of excellence warrants it.

As regards the fleece it was shown that skin folds tend to produce stronger wool on the folds than is grown between the folds and in consequence an uneven fleece is produced by a developed animal. In addition a plain-bodied sheep has a more uniform fibre distribution than a developed animal and in

this respect is preferable. It has also been shown that the lack of fibre uniformity is a defect in wool when it is compared with synthetic fibres. Where an improvement in fibre uniformity is the aim, the breeding of plain-bodied type of merino is therefore preferable.

It has also been observed that the tips of the wool grown on the skin folds are drier and more brittle than those grown between folds. Since brittle tips tend to produce more noil in the combing processes than do greasy tips, this point is also one in favour of the plain-bodied merino.

Apart from the fleece, there are many practical considerations pointing to the desirability of breeding the plain-bodied merino in South Africa. The disadvantages of the developed type are numerous. Firstly, the physical constitution of the plain-bodied type is better than that of the developed type, secondly, lambs from developed ewes suckle with difficulty, and thirdly, the shearing of folded sheep is more troublesome. Finally, the developed merino is more liable to blowfly attacks (Smit (1931)). In regard to the latter an illuminating series of experiments was published by the Australian Joint Blowfly Committee, (1933) and the investigations definitely demonstrated the disadvantages of skin folds where the blowfly menace was a consideration.

The advantages of the plain-bodied type of merino over the developed type are numerous. There are, however, problems associated with the study that need further investigation. It has been asserted by breeders that it is possible to obtain bulk of fleece by skin folds and that the quickest method of procuring this is by introducing skin folds. It has also been declared that a certain degree of development is necessary in stud rams, as the tendency of developed rams is to beget plain-bodied offspring that lack fleece density. There are other important breeding problems associated with the study, such as the relative prepotency of the two types. These problems need more experimental evidence, and are embodied in further research for which special breeding experiments are now in progress. The results are, however, not yet available.

In discussing the standards of excellence of merino sheep, the question of yield inevitably arises since in South Africa raw wool is sold in the grease and the price per pound is largely based on the buyers' estimate of the yield.

The determinations of yield, which were recorded on stud rams and stud ewes that were run on the same farm during the same season, showed a variability of from 32·3 per cent. to 57·0 per cent. The wool buyer who estimates the yield of any one clip must therefore consider the average yield of the clip and for any reliable estimate, a thorough system of sampling the clip is essential. If the fleeces of the ewes and those of the rams in the present study are assumed to be representative of stud sheep, the statistical analysis of the type shows that approximately 640 fleeces are necessary for a reliable mean which can fluctuate within one per cent. of the yield.

The large variability in yield that occurs in the same flock of merinos has made the determination of yield an extremely difficult one, and, since the valuation of the clip largely depends on the sampling of the clip, a very important one. Yield is dependent on the relative proportions of impurities and wool present in the fleece, (Bosman (1935)) and an analysis of the relationships between the total fleece, its yield and its impurities, shows that the impurities consist of the secretions of the sebaceous and sudoriferous glands of the skin, as well as of the foreign matter such as sand and grass seeds. It is the foreign matter that largely determines the differences in the yield of merino wool from different areas of the Union, and it is not uncommon to find wools from grassveld areas of the Union yielding 60 per cent. and even higher. Wool from more sandy areas, such as certain north western districts of the Cape Province, have produced clips with yields as low as 25 per cent. and even less.

In considering the question of environmental influences on wool production the nutrition experiments have demonstrated that the quantity and quality of the fleece can be considerably changed by changing the nutrition. These experimental results are in agreement with those of overseas workers who, however, studied breeds of sheep other than the merino.

The standard of excellence of a merino sheep is therefore very largely dependent on the way in which the animals are fed during the time the fleece is grown. If sheep are subjected to differing planes of nutrition, the differences are evidenced in the wool staple. Good feeding produces a larger and coarser fleece, whilst malnutrition produces a smaller and finer fleece. Since the market value of fine wool is slightly higher than that of coarse wool the sheep farmer expects a higher price per pound of wool during droughts, but at the same time there is a diminution in the quantity of wool produced per sheep. It is important to the farmer to know whether the loss sustained by quantity of wool is compensated for by an increase in the price paid per pound for the finer quality. The experimental results give the quantity and quality of wool produced by feed changes, and if the qualities of the experimental groups were 70's and below it would be possible to give an answer to the question. However, quotations on the open market do not include quality numbers finer than 70/80's and it is, therefore, not possible to differentiate between the values of 120/150's and that of 90's. It appears, however, that the quantity of wool obtained from the two planes of nutrition namely 4·21 pounds and 5·55 pounds (or a difference of 31·8 per cent.) is a bigger factor in the problem of the returns per sheep than that of the quality differentiation.

According to the ruling market prices the experimental group of animals producing 4·21 pounds and 5·55 pounds of wool respectively will return 7/9 per sheep in the former case and 9/4 per sheep in the latter case. This means that a difference of 7d. per pound (on the clean scoured basis) is necessary for the underfed sheep to give the same return as the well-fed sheep. Although no actual quotations are available for quality differences among the finest quality numbers such as 90's and above, the range of quality numbers from 60's to 70's is differentiated at the most by 5d. per pound on a clean scoured basis. Economically, therefore, the wool of underfed sheep cannot be favourably compared with normally grown fleeces.

The marked influence of feed on the fleece is important when the hereditary characteristics of the merino are studied, and a control of the rations of the animals is essential. Comparisons of the fleece attributes are thus placed on a reliable basis for study from one generation to the other. The effect of the plane of nutrition is of great significance to the merino stud breeder, since the characteristics of stud sheep can be changed to a marked degree simply by changing the feed. These changes have often been the cause of disappointment to breeders, when well-fed animals, bought at high prices, have been placed on the veld with less available food. The resultant reduction in fibre fineness produced a loss of fleece density, and the compactness of the fleece was reduced considerably. Less wool was produced, and the standard of excellence was lowered. Experimental results showed that wool production was not changed in an extremely varying Karroo climate, provided the feed was kept constant, and it therefore appears likely that when such changes do occur they are due to a nutritional factor controlled by varying pastures.

It is of the greatest importance to know how the genetic characteristics of such a variable merino will behave in breeding and studies concerning this are still in progress. When breeding for certain fleece characteristics in a definite direction, other fleece characteristics may tend to be accentuated also in a definite direction. For instance, the sheepman who constantly selects for small crimps, or a large number per inch, will tend to breed towards a fine fibred wool. Such definite relationships are a valuable guide in breeding practice and sheep breeders have

asserted that there are many such relationships among fleece characteristics. The extent to which this is true can only be determined when observations are based on data where the characteristics are expressed in arithmetical terms. In the study it has been disappointing that so few definite correlations were found to exist between the numerous fleece characteristics and of these it is intended to discuss only those that are of value for practical application.

In the analyses of the stud ewes it was shown that the quantity of wool produced per unit area of skin and the fleece density on belly regions were definitely correlated with the scoured fleece weight. This was not the case with the shoulder regions, where the correlation was indefinite. The belly region can thus be used by the sheep judge as an indicator of the scoured fleece weight.

The definite relationship between yield and the straight fibre length of the fleece is useful since it establishes that cleaner wools tend to be longer fibred.

There is a definite relationship between the number of fibres growing per unit area on the belly region and the number of fibres growing per unit area on the shoulder regions, and a sheep, dense on the shoulder, will tend to be dense on the belly also.

It has been asserted by sheepmen that the characteristics, shortness of fibre and fineness of fibre, are correlated, but no such relationship could be found in the shoulder or belly regions of the ewes analysed. This finding agrees with that of Davenport and Ritzman, who state that " there appears to be no physiological dependence of small diameter on shortness of fibre."

As regards the relationship of the fleece characteristics of stud rams, definite correlations were established on sixteen rams of one stud breeder, but in view of the anomalies recorded in Table XXIII, the practical application of the results needs consideration.

In stud breeding where controlled mating is practised farmers require fewer rams than formerly and these stud rams can be of a correspondingly higher standard. Since the aim of this controlled mating is to obtain as many lambs as possible from the rams that possess and transmit desirable characteristics it is of greater advantage to select rams on a complete fleece analysis basis rather than to rely on the analysis of some of the characteristics, and then to assume that the remaining characteristics will conform to the relationships given in the table. For example, the breeder who bases selection on greasy fleece weights would expect, according to the coefficients of correlation, that the higher weights would give a greater scoured fleece weight, greater fibre fineness and greater fleece density. The values for these coefficients of correlation are not very high and since this is the case, the author believes that, when a few rams only are used in a stud, selection on complete fleece analysis is of greater advantage to the breeder. It must however be pointed out that, where the mass is concerned, the coefficients of correlation that are definite, are useful, especially where it is not possible to analyse all the characteristics of a large number of individuals.

Records of fleece characteristics are becoming of greater importance to the stud breeder and there are indications that sheep selection of the future will have to be based on fleece analyses. Little is known of the characteristics of the outstanding merino stud rams that in the past made merino history, and apart from the fact that some of these sheep gained many successes at sheep shows and were sold for large sums of money, in some cases thousands of pounds, there has been no definite system of recording fleece characteristics to show why these animals were so highly valued. Nor do the progeny of these rams have precise records that accurately indicate their potential production and performance.

It has been conclusively demonstrated in the Friesland cattle industry that a system of controlled recording has established a high standard of excellence for production and performance and it is reasonable to believe that a similar system would be equally successful in the merino breeding industry.

If stud rams were selected on the basis of production and performance, progress in sheep breeding would inevitably result. Since definite methods of

fleece analyses have been worked out, and the stress that each fleece characteristic deserves in sheep selection has been clearly defined, it is possible to visualise the day when only sheep that conform to definite recorded standards of excellence, based on precise arithmetical expressions, will be registered as stud animals. The adoption of fleece recording methods would place the sheep breeding industry on a sounder basis which could only reflect favourably on South African wool production.

In conclusion, it must be pointed out that the studies have by no means exhausted investigations into the biological aspects of South African merino wool production. On the contrary, they have shown that the subject offers a vast field for the application of scientific research, which can very profitably be linked with the physical and the chemical aspects of South African merino wool production. There is every reason to believe that the results of such research will prove to be a valuable asset to the sheep and wool industry of the future.

SUMMARY AND CONCLUSION

Laboratory methods that are most suitable for routine analysis of merino fleece characteristics are described. The importance of precise arithmetical expressions for fleece characteristics is emphasised.

It is shown that fleece density is dependent on the number of fibres growing per unit area of skin as well as on the fineness of the fibres.

A formula is given by which the scoured fleece weight can be calculated.

$$W = LAdns.$$

Where W is fleece weight, L, fibre length, A, cross-sectional area of the fibres, d, specific gravity of wool, n, number of fibres grown per unit area of skin and s, total skin area of the sheep.

The merino slide rule, whereby fleece characteristics can conveniently be compared in relation to wool production, is described. The stress that each fleece characteristic deserves in sheep selection is established.

It is shown that fleece weights, fibre fineness and fleece density are appreciably changed by changing the plane of nutrition of merino sheep. By malnutrition the quantity of wool can be reduced by 31·8 per cent., the fibre fineness by 33·4 per cent. and fleece density by 36 per cent. A 64's quality number can be refined to a 150's quality number and the finer quality number can be restored to the coarser by good feeding. Feed does not influence fibre contour significantly.

The merino sheep does not show seasonal changes in wool production in a varying Karroo climate, provided the feed is kept constant.

Pregnancy does not influence the fibre fineness of merino wool significantly but lactation and the suckling of lambs reduce the fibre fineness, the fleece density and the wool production appreciably.

A detailed account, based on a measurement of a quarter of a million fibres, is given of the fibre fineness of South African merino wool, which ranges from $7{\cdot}5\mu$ to 50μ with a mean of $19{\cdot}1\mu$, a 66's quality number. The bulk, or eighty per cent. of the fibres, measures from $12{\cdot}5\mu$ to $22{\cdot}5\mu$, eighty per cent. conform to the quality number of 60's to 100's, eleven per cent. are 120's to 150's and eight per cent. are coarser than a 60's quality number.

The significant coefficient of correlation of $-0{\cdot}617 \pm 0{\cdot}0226$ between fibre fineness and crimping is analysed from the woolman's point of view. It is shown that only twenty-eight per cent. of merino wool shows perfect agreement between fibre fineness and crimping. The woolman who judges fibre fineness on crimping can err in seventy-two per cent. of his estimates. On the whole, under estimates and over estimates even up.

Merino stud ram wool is found to be coarser in fibre fineness than the crimps indicate. It is shown that 16·3 per cent. of the Union's stud rams show an agreement between fibre fineness and crimps, while 8·9 per cent. are finer in

fibre fineness than the crimps indicate, and 74·8 per cent. are coarser in fibre fineness than the crimps indicate.

It was found that the coefficient of fibre variability of South African commercial wool ranges from ten to thirty-two per cent. coefficient of variation and seventy-nine per cent. of the samples range from sixteen to twenty-four per cent. coefficient of variation. Eleven per cent. are more uniform, with ten to sixteen per cent. coefficient of variation, whilst ten per cent. are more variable with a range of twenty-four to thirty-two per cent. coefficient of variation.

It is shown that when merino sheep with extremes of fibre fineness are mated the F.1. generation has a fineness that is intermediate between the parental types and produces a less uniform wool than that of the parents.

In stud ram wool there was found to be a significant coefficient of correlation between fibre fineness and the factors of crimps per inch ($-0{\cdot}426 \pm 0{\cdot}0498$) and standard deviation ($+0{\cdot}677 \pm 0{\cdot}0327$). There was no significant correlation between crimps per inch and the factors standard deviation and coefficient of variability and no significant correlation between standard deviation and coefficient of variation.

A fleece analysis of sixteen stud rams showed that on the average a stud ram produces ten pounds of clean dry wool per annum. On the shoulder there are 2·22 grams of clean wool and 39,400 fibres are produced per square inch of skin. The fibre fineness measures $22{\cdot}02\mu$, a 60's quality number.

Certain correlations between the fleece characteristics of stud sheep are established.

In an experiment with twenty-six merino stud ewes it is shown that the average production of each individual is seven pounds of clean dry wool per annum—1·38 grams of wool per square inch of skin—46,500 fibres per square inch on the shoulder and a wool of 64's quality number. Yield varies from 32·2 per cent. to 53·0 per cent. among these sheep which were grazed on the same farm in the same flock.

The relative merits of plainbodied and developed merino sheep are discussed. It is shown that the plainbodied sheep can have the same standard of excellence as regards the fleece characteristic as the developed sheep, and in addition, the plainbodied sheep produces a fleece that is more uniform in fibre fineness than the developed animal. It is, therefore, preferable to the developed type.

From the available data it appears that South African merino sheep have a greater number of fibres per square inch of skin than the Rambouillet sheep of America.

It is suggested that for the purpose of improving South African wool production a system of fleece recording, based on precise arithmetical expression of the fleece characteristics, be employed in merino stud breeding.

ACKNOWLEDGMENTS

The author is indebted to the Grootfontein School of Agriculture and also to private merino stud breeders for material used in the studies.

He is glad to have this opportunity of acknowledging the inspiration derived from his early association with Professor J. E. Duerden, formerly Director of Wool Research for the Union of South Africa, and he acknowledges gratefully the courtesy of Dr. P. J. du Toit, Director of Veterinary Services, for facilities for carrying out this work.

He is indebted to Mr. A. P. Malan, M.Sc., Statistician at Onderstepoort, for certain of the correlation tables and to Mr. C. G. Walker, and Mr. T. Meyer for the excellent illustrations and plates which appear in the study.

BIBLIOGRAPHY

American and Delaine-Merino Record Association, "The Merino Sheep." Xenia, Ohio.

Annual Report (1933). Dept. of Agric. *Farming in SA.* Vol. 8, No. 93, Dec.

BAILEY, P. G. (1914). "Preliminary Note on Wool Inheritance." *British Association Report*, pp. 654-5.

BARKER, S. G., and KING, A. T. (1926). "A Comparison of Measurements of Diameters of Wool Fibres with the Microbalance and the Projection Microscope, with Applications to the Determinations of Density and Medulla (Kemp) Composition." *J. Text. Inst.*, Vol. 7, No. 1, pp. 68-74.

BARKER, S. G., and FROBISHER, A. (1927). "The British Research Association for the Woollen and Worsted Industries. An Outline of its Activities." No. 78. Leeds, p. 45.

BARKER, S. G., and BURGESS, R. (1928). "Some Characteristics of Wool as affecting Worsted Spinning." *Bull. No.* 87. *British Research Association for the Woollen and Worsted Industries*, pp. 35.

BARKER, S. G., and MARSH, M. C. (1928). "A fibre Comparator. A Simple Projection Microscope for the Comparison of Fibre Diameters." *British Research Association for the Woollen and Worsted Industries. Publication No.* 97, 10 pp.

BARKER, S. G. (1929). "Wool, a Study of the Fibre." *Empire Marketing Board, No.* 21. London. 166 pp.

BARKER, S. G., and WINSON, C. G. (1929). "Memorandum on the Physical Analysis of the Romney, Corriedale, and Romney-Corriedale Cross-bred Fleeces." *Bull. of the Imp. Inst.*, Vol. 28, No. 2, pp. 150-161.

BARKER, S. G. (1929). "The Scientific Measurement of the Attributes of the Wool Fibre and their Inheritance as a Link between Producer and Manufacturer with particular reference to S.A. Wool." *British Research Association for Woollen and Worsted Industries.*" 28th June. 24 pp.

BARKER, S. G. (1929). "Production of the Ideal Fabric." *Wool Rec. and Text. World*, Vol. 36, No. 1074, pp. 1689-1693 ; 1765-1767 ; 1833-1859.

BARKER, S. G., and NORRIS, M. H. (1930). "A Note on the Physical Relationship in Wool." *J. Text. Inst.*, Vol. 21, pp. T1-T17.

BARKER, S. G. (1931). "Wool Quality." H.M. Stationery Office, London, 328 pp.

BARKER, S. G. and WINSON, C. G. (1931). "Note on the Relationship of Fibre Fineness and Wool Quality in Combed Tops." *J. Text. Inst.*, Vol. 22, 6, pp. T314-T519.

BARRITT, J., and KING, A. T. (1926). "The Sulphur Content of Wool." *J. Text. Inst.*, Vol. 17, pp. T386-395.

BAUR, E., and KRONACHER, C. (1919). "Gibt es konstante intermediäre Rassenbastarde in der Schafzucht ?" *Deut. Landw. Presse*, pp. 713-14.

BEDELL, G. H. (1933). "Judging Sheep." *U.S.A. Dept. of Agric. Farmers Bull., No.* 1199, Washington, D.C., 17 pp.

BLOWFLY COMMITTEE, THE JOINT (1933). "The Sheep Blowfly Problem in Australia." *Report* 1, *Counc. for Sci. and Indust. Res. Bull. No.* 40, Jan., 136 pp.

BOSMAN, V. (1927). "Standardisation of Wools, Crimps and Quality Counts." *S.A. J. of Sci.*, Vol. 24, pp. 422-423.

BOSMAN, V. (1931). "Research and the Merino Sheep Breeder." *S.A. J. Sci.*, Vol. 28, p. 306-307.

BOSMAN, V., and MARÉ, G. S. (1933). "Merino Stud Ram Wool." *Farmers' Weekly.* Bloemfontein, April 24th.

BOSMAN, V. (1934). "Fleece Density in the Merino Sheep." *Farming in S.A.*, Vol. 9, No. 96, March.

BOSMAN, V. (1934). "Precision in Judging and Classifying the Merino Fleece." *Farming in S.A.*, Vol. 9, No. 88, p. 194 (May).

BOSMAN, V. (1935). "Merino Wool compared with Wollstra." *Farming in S.A.*, Vol. 10, No. 12, July, pp. 291-292.

BOSMAN, V. (1935) "The Importance of Yield in the Merino Wool Production." *Farming in S.A*,. Vol. 10, No. 3, June, pp. 244-245.

BOTHA, P. S. (1930). "The Transformation of the Birth Coat of the Merino into the Fleece of the Adult." *Thesis for M.Sc. degree, Univ. of S.A.* (Not published.) 75 pp.

BOTHA, P. S. (1931). "Density in the Merino Fleece." *S.A.J. of Sci.*, Vol. 28, pp. 311-312.

BOTHA, M. L. (1936). "An Improved Method of Scouring Merino Wool." (In course of preparation.)

BOYD, EVELYN (1927). "The Primitive Coat of the Blackhead Persian." *S.A. J. Sci.*, Vol. 24.

BURNS, R. H., and KOEHLER, W. B. (1925). "The Micrometer Caliper as an Instrument for Measuring the Diameter of Wool Fibres." *Bull. No.* 141, *Univ. of Wyoming* 28 pp.

BURNS, R. H. (1926). "Wool Analysis: Density Determinations." *Wool. Rec. and Text. World*, Vol. 30, 902, p. 555.

BURNS, R. H. (1929). "Comparative Wool Measurements of Australian (Wanganella) Merinos and American Rambouillets." *The Pastoral Review*, March, pp. 257-8.
BURNS, R. H. (1929). "Wool Measurements Technic." *Rec. of Proceedings Am. Soc. of Animal Production.*
BURNS, R. H. (1931). "Monthly Wool Growth of Rambouillet Ewes." *J. Text. Inst.*, Vol. 22, No. 2, pp. T98-109.
BURNS, R. H. (1931). "Monthly Wool Growth Studies II." (*a*) Hampshire Down Ewes. (*b*) Corriedale Ewes. *J. Text. Inst.*, Vol. 22, T456.
BURNS, R. H., and MILLER, W. C. (1931). "Sampling Instruments to determine Fleece Density in Sheep." *J. Text. Inst.*, Vol. 22, No. 12, Dec., pp. T547-564.
BURNS, R. H. (1933). "Wool Inheritance in Hampshire-Rambouillet Cross Breds." *Bull. No.* 196, *Univ. of Wyoming*, April, 21 pp.
BURNS, R. H. (1933). "The Nutritional and Genetic Aspects of Wool Production." *Univ. of Wyoming. Reprinted from Rec. of Proceedings Am. Soc. of Anim. Production*, pp. 164-169.
COFFEY, W. C. (1929). "Productive Sheep Husbandry." *Lippincott's Farm Manuel*; Philadelphia, 479 pp.
COWGILL, G. R., and DRABKIN, D. L. (1927). "Determination of the Formula for the Surface Area of the Dog together with a consideration of Formulae available for other Species." *Amer. Jour. of Phys.*, Vol. 81, No. 1, pp. 36-61.
CREW, F. A. E. (1921). "On the Fleeces of Certain Species of Sheep." *Ann. of Appl. Biol.*, Vol. 8, Nos. 3 and 4, Nov., pp. 164-169.
DANTZER, J., and ROCHRICH, O. "Contribution à l'étude des laines Finesse et qualité." *Rev. Text.*, 6, pp. 773-737. Paris.
DARLING, F. F. (1932). "Studies in the Biology of the Fleece of the Scottish Mountain Blackface Breed of Sheep." *Zeitschr. f. Tierz.*, Vol. 24, 3.
DAVENPORT, C. P., and RITZMAN, E. G. (1926). "Some Wool Characters and their Inheritance." *New Hampshire Exp. Sta. Bull.* No. 31, July, 58 pp.
DUERDEN, J. E., and RITCHIE, M. I. F. (1924). "Development of the Merino Wool Fibre." *S.A. J. Sci.*, Vol. 21, pp. 480-497.
DUERDEN, J. E., and BOSMAN, V. (1926). "Wool Analysis and Breeding." *Farmers' Weekly*, 27th Jan.
DUERDEN, J. E., and BOSMAN, V. (1926). "A Biometrical Analysis of Merino Wools." *Sci. Bull. No.* 44, *Dept. of Agric. Union of S.A.*, Pretoria. 16 pp.
DUERDEN, J. E., and BOSMAN, V. (1927). "Absence of Uniformity in Growth of the Merino Fleece." *J. Text. Inst.*, Vol. 18, pp. T191-194.
DUERDEN, J. E., and SEALE, P. M. (1927). "A new Type of Fibre in the Merino." *J. Text. Inst.*, Vol. 18, pp. T265-T273.
DUERDEN, J. E. (1927). "Evolution in the Fleece of Sheep." *S.A. J. Sci.*, Vol. 24.
DUERDEN, J. E. (1929). "Standards of Thickness and Crimps in Merino Grease Wools." *J. Text. Inst.*, Vol. 20.
DUERDEN, J. E. (1929). "Wool Research in South Africa." *Paper No.* 64, *Pan-African Agricultural and Veterinary Conference*, Dept. of Agric., Pretoria, pp. 34-50.
DUERDEN, J. E., and BOSMAN, V. (1929). "Standardisation of Wool." *Reprint No.* 30. *Farming in South Africa.* April.
DUERDEN, J. E. (1929). "The Zoology of the Fleece of Sheep." *S.A. J. Sci.*, Vol. 26, pp. 459-469.
DUERDEN, J. E., and BOTHA, P. S. (1930). "Density Variation in the Fleece of the Merino." *S.A. J. Sci.*, Vol. 27.
DUERDEN, J. E., and WHITNALL, A. B. M. (1930). "Seasonal Variation in the Coat of some Domestic Mammals." *S.A. J. Sci.*, Vol. 27, pp. 521-545.
DUERDEN, J. E. (1927). "Studies on Sheep and Wool." *Sci. Bull. No.* 59, *Dept. of Agric.*, Pretoria.
DUERDEN, J. E., and BOSMAN, V. (1931). "Fibre Lengths, Thicknesses and Qualities in a Single Wool Staple." *17th Rept. Dir. Vet. Serv. and Anim. Indust.*, Union of S.A., pp. 771-779.
DUERDEN, J. E., and BOSMAN, V. (1931). "Staple Length and Crimped and Straight Length of Merino Wool Fibres." *17th Rept. Dir. Vet. Serv. and Anim. Indust.*, Union of S.A., pp. 781-787.
DUERDEN, J. E., and BELL, D. G. (1931). "Quality Variation and Distribution in the Fleece of the Merino." *17th Rept. Dir. Vet. Serv. and Anim. Indust.*, Union of S.A., pp. 789-811.
DUERDEN, J. E., and MARÉ, G. S. (1931). "Rates of Growth of Merino Wool Month by Month." *17th Rept. Dir. Vet. Serv. and Anim. Indust.*, Union of S.A., pp. 807-811.
DUERDEN, J. E., BOSMAN, V., and BOTHA, P. S. (1932). "Influence of Phosphorus and other Minerals on Wool Growth." *18th Rept. of the Dir. Vet. Serv. and Anim. Indust.*, pp. 631-649.
DUERDEN, J. E., MURRAY, C. A., and BOTHA, P. S. (1932). "Growth of Wool in the Merino." *18th Rept. of the Dir. Vet. Serv. and Anim. Indust.*, Part II, pp. 973-990.

DUERDEN, J. E., and PALMER, E. W. (1932). "Staple Length Variation and Distribution in the Fleece of the Merino." *18th Rept. of the Dir. Vet. Serv. and Anim. Indust.*, pp. 991-1003.
DOEHNER, H. (1929). "Eine Methode zur objectiven Feinheitsbestimmung von Wollhaaren und Textilfasern." *Melliand Text., Ber.* Nr. 3.
DOEHNER, H. (1935). "Die Feinheit und Festigkeit der Deutschen Schafwollen." *Reichsverband Deutscher Schafzüchter*, Berlin, 194 pp.
ELPATJEVSKY, D. W. (1929). "Methods of improving Coarse Woolled Sheep." (Translated title.) *Bull. Live Stock Breed.*, No. 9, pp. 71-79.
EMPIRE MARKETING BOARD (1932). "Wool Survey," No. 37. H.M. Stationery Office, London, 220 pp.
EWART, J. C. (1919). "The Inter-crossing of Sheep and the Evolution of New Varieties of Wool." *Scot. J. Agric.*, Vol. 2, pp. 159-169.
EWLES, J. (1928). "A Simple Optical Method for Determining Rapidly the Mean Diameters of a Number of Fibres." *J. Text. Sci.*, Vol. 2, pp. 101-102.
FISHER, R. A. (1922). "Statistical Methods for Research Workers." *4th Ed., Oliver and Boyd*, Edinburgh.
FRASER, K. M. (1931). "The Rate of Growth of the South Australian Merino Fleece." *J. of the Counc. for Sci. and Indust. Res.*, Nov.
GAVAZZI, G. (1934). "A Hint to Research of an Objective Method for Wool Testing." *Rept. of the Tenth International Wool Conf.* Rome. 9 pp.
GUTHRIE, J. F. (1927). "The Australian Sheep and Wool Industry." The Victorian Historical Magazine. Vol. 12, No. 1, Melbourne. 20 pp.
HANDBOOK FOR FARMERS IN S.A. (1929). Govt. Printer, Pretoria, 766 pp.
HARDY, J. I., and TENNYSON, J. B. (1930). "Wool Fineness as Influenced by Rate of Growth." *J. Agric. Res.*, Vol. 40, No. 5, pp. 457-467.
HENRY, W. A., and MORRISON, F. P. (1923). "Feeds and Feeding." 18th Edition.
HENSELER, E. (1926). "On the Question of the Standardisation of Wool in the Preparation of International Wool Statistics." *Int. Rev. Sci. and Pract. of Agric.*, Rome. Vol. 4, 3, pp. 514-534.
HERTZOG, A. (1926). "Neues Verfahren zur Herstellung vom Faserquerschnitten." *Melliand's Textilber* 7.
HEYNE, J. (1924). "Die Wollkunde." Leipzig. 142 pp.
HILL, J. A. (1923-24). *34th Ann. Rept. Wyoming Agric. Stn.*
HULTZ, F. S., and PASCHAL, L. J. (1930). "Wool Studies with Rambouillet Sheep II." *Bull.* 174, *Aug. Exp. Stn. Bull.*, Laramie, Wyoming. 31 pp.
IVANOV, M. F., and BELEHOV, P. P. (1928). "Inheritance of Quality of Wool by F1 from Crosses of Various Breeds with Lincolns." (Translated title.). *Chapli. Zoot. Exp. Stn. Bull., No.* 3, pp. 7-48.
JONES, J. M., and WARWICK, B. L. (1930). "Relation of Skinfolds to Weight of Fleece on Rambouillet Sheep." *43rd Ann. Rept. Texas Agric. Exp. Stn.*, pp. 22-23.
KING, A. T. (1926). "The Specific Gravity of Wool and its Relation to Swelling and Sorption in Water and other Liquids." *J. Text. Inst.*, Vol. 17, T53.
KRAUTER, G. (1929). "Über die Wollfeinheitsmessung." *Text. Forschung.*, 68 pp. Dresden. April.
KRONACHER, C., and LODEMANN, G. (1929). "Technik der Haar- und Wolluntersuchung." *Urban and Schwarzenberg*, Berlin. 432 pp.
LINES, E. W., and PEIRCE, A. W. (1931). "The Basal (Standard) Metabolism of the Australian Merino Sheep." *Bull. No.* 55, *Counc. for Sci. and Indust. Res.*, Melbourne. 34 pp.
MILLER, Wm. C., and BRYANT, D. M. (1932). "An Apparatus for Scouring Small Samples of Wool and a Modified Apparatus for Determining Dry Weights." *J. Text. Inst.*, Vol. 23, Nov., pp. T267-273.
MILLER, Wm. C. (1933). "A General Review of the Inheritance of Wool Characters in Sheep." *The Emp. J. of Exp. Agric.*, Vol. 1, No. 2, July.
NATIONAL WOOL GROWERS ASSOCIATION (1934). "Wool Classing Standards." Dept. of Agric., Pretoria.
NEW NATION MAGAZINE (1935). "Forty Years of Sheep Breeding. The Development of the Merino Ram in Australia as exemplified at the Sydney Sheep Show." June 15, pp. 16-23.
NICHOLS, J. E. (1932). "A Study of Empire Wool Production." *Wool Industries Research Association*, Leeds. 148 pp.
NORDBY, J. F. (1928). "The Idaho Wool Caliper and its Application in making Density Determinations." *Idaho Agric. Stn. Circular No.* 52, 8 pp.
PALMER, E. W. (1931). "Staple Length Variations in the Fleece of the Merino." *S.A. J. Sci.*, Vol. 28, pp. 308-310.
PAZZINI, F. (1915). "Contributo Allo Studio del Miglioramento della pecore nella Media Valle del Tevero." *Le Stazione Sperim. Agrar. Italiane*, 48.
PEIRCE, A. W. (1934). "The Basal (Standard) Metabolism of the Australian Sheep–II." *Bull. No.* 84, *Counc. for Sci. and Indust. Res.*, Melbourne. 21 pp.
PLAIL, J. (1930). "Die Technische Qualitätsbestimmung der Wolle auf Grund der Schneiderschen Feinheitsskala." *Melliands Textilber.*, Vol. 11, No. 7.

PROBST, E. (1926). "Die Feinheitsbestimmung des Wollhaares." *Ztschr. Tierzuchtung u. Zuchtungsbiol.*, 6, p. 405.
RAPPORT VAN KONFERENSIE VAN GOEVERNEMENTS SKAAP EN WOLBEAMPTES GEHOU TE GROOTFONTEIN LANDBOUSKOOL (1934). Dept. van Landbou., Pretoria. 26 Mei.
RAUSCH, H. (1934). "About the use of Exact Methods for Measuring the Fineness of Wool Fibres." *Rept. of the 10th Internat. Wool Conf.* Rome. 13 pp.
RAUSCH, H. (1935). "Scientific Methods for the Examination of the Wool Fibre, Practical Application." *Fils et Tissues*, Vol. 23; 409-423, 489-499, 579-585, and 635-641.
RAUSCH, H. (1935). "New Exact Methods for Judging Wool Fibres." *Rept. of the 11th Internat. Wool Congress*, Berlin, pp. 1-10.
REIMERS, J. H. W. T., and SWART, J. C. (1929). "Variation in Diameter and Crimp of Wool of Different Parts of the Body of Merino Sheep." *Sci. Bull. No.* 83, *Dept. of Agric.*, Pretoria, 60 pp.
REIMERS, J. H. W. T., and SWART, J. C. (1931). "Correlation between Crimp and Diameter of Wool." *S.A. J. of Sci.*, Vol. 28, pp. 315-322.
REPORT OF THE AGRICULTURAL AND PASTORAL PRODUCTION (1928-29). Office of Census and Statistics, Pretoria.
REPORT OF THE AGRICULTURAL AND PASTORAL PRODUCTION (1930, 1931). Office of the Census and Statistics. Pretoria.
ROBERTS, J. A. FRASER (1926). "The Cotted Fleece." *J. Text. Inst.*, Vol. 17, pp. T171-179.
ROBERTS, J. A. FRASER (1926). "Kemp in the Fleece of the Welsh Mountain." *J. Text. Inst.*, Vol. 17, pp. T274-T290.
ROBERTS, J. A. FRASER (1927). "A New Method for the Determination of Fineness of Wool and of the Fleece." *J. Text. Inst.*, Vol. 18, pp. T48-54.
ROBERTS, J. A. FRASER (1930). "Fleece Analysis for Biological and Agricultural Purposes I. The Average Fineness of a Sample of Wool." *J. Text. Inst.*, Vol. 21, No. 4, pp. T127-164.
ROSE, P. D. (1930). "Interpretation of the Merino Score Card." *Farming in S.A.*, March, Reprint No. 20, Dept. of Agric., Pretoria.
ROSE, P. D. (1931). "Breeding and Classing of Merino Sheep." *Farming in S.A.*, April.
SCHNEIDER, D. (1934). "Wool Quality Classification." *Text. Merc. and Argus*, Vol. 90, 565-569.
SCHNEIDER, D. (1934). "About the Present State of the Studies on the Technical Characteristics of the Wool Fibre." *Rept. of the 10th International Wool Conf.* Rome. 3 pp.
SCHUURMAN, G. J. (1931). "Position of South African Wool on Overseas Markets." *Wool Council, No.* 3. Govt, Printer, Pretoria. 19 pp.
SEVER, W. (1932). "The Measurement of Fibre Length." *J. Text. Inst.*, Vol. 23, No. 7, pp. P151-161.
SMIT, BERNARD (1931). "A Study of the Sheep Blowflies of South Africa." *17th Rept. of the Dir. Vet. Serv. and. Anim. Indust.* Onderstepoort. pp. 299-421.
SNELL, M. G. (1931). "Shedding of Wool by Louisiana Sheep." *Proc. Amer. Soc. Animal Product.*
SPEAKMAN, J. B., STOTT, E., and CHANG, H. (1933). "A Contribution to the Theory of Milling, II." *J. Text. Inst.*, Vol. 24, pp. T273-292.
SPENCER, D. A., HARDY, J. I., and BRANDON, M. J. (1928). "Factors that influence Wool Production with Range Rambouillet Sheep." *Tech. Bull. No.* 85.
SPÖTTEL, W. (1925). "Über Variabilität, Korrelative Beziehungen und Vererbung der Haarfeinheit bei Schafen." *Bibliog. Genet.*, 7.
TÄNZER, E., and SPÖTTEL, W. (1922). "Das Zackelschaf unter Berücksichtigung der Zuchten des Landwirtschaftlichen Instituts der Universität Halle." *Ztschr.*
TERHO, T. (1923). "Zur Vererbung einiger Wollkarakter beim Meleschaf." *Ztschr.*
VAN WYK, C. M. (1935). "A Comparison of the Weight-Length and Microscopic Methods of Determining the Fibre Fineness of a Sample of Wool." (Report in preparation.)
WEBER, A. D. (1931). "The Effect of the Plane of Nutrition of Wool Growth." *Proc. Amer. Soc. Anim. Product.*, Kansas State Coll.
WILSON, J. F. (1927). "Wool Production in California." *Calif. Agr. Exten. Serv., Circular No.* 12, April.
WILSON, J. F. (1928). "A Method of Determining the Clean Weight of Individual Fleeces of Wool." *Bull. No.* 447, *Univ. of Calif.*, Berkeley, 42 pp.
WILSON, J. F. (1931). "The Influence of the Plane of Nutrition upon Various Factors Related to Wool Production." *Nat. Wool Grower*, Vol. 21, Univ. of California, Dec.
WINSON, C. G. (1929). "Some Physical Characters of Greasy and Non-greasy Fleece Wools." *J.Text. Inst.* 20. pp. T219-T232.
WINSON, C. G. (1931). "A Comparison of the Fineness of British and Continental Standards for Combed Tops." *J. Text. Inst.*, Vol. 22, pp. T533-546.
WOOD, T. B., and CAPSTICK, J. W. (1926). "The Maintenance Requirements of Adult Sheep." *J. Agric. Sci.*, Vol. 16, pp. 325-333.
WOOL RECORD AND TEXTILE WORLD (1936). "Topics of the Week." 9th Jan., p. 61.

Reviews

Kolloidchemische Grundlagen der Textilveredlung. (Colloidchemical Basis of Textile Processing.) By Dr. Emmerich Valko. Berlin, Julius Springer, 1937. 57 RM. Bound 60 RM. pp. 701, 346 figures.

This work (dedicated to Prof. W. Pauli) has been written to collect modern researches on the constitution, molecular and crystal structure of fibrous materials, their physical properties, moisture relations and the related work on the colloid chemistry of the dyebath, the dyeing process, washing, wetting and emulsification processes.

Sections 1 to 10 (the first half of the book and 300 pages of it) are devoted to the fundamental structure of cellulose, wool, keratin, silk, proteins, their morphology, histology and micellar texture (Sections 1-3). Section 4 deals with the absorption of water and comparison of the fibres including dimensional changes.

Section 5 considers wool and silk as amphoteric electrolytes. The mercerisation of cotton is given a long section (7) of 64 pages.

Section 8 deals with characterisation of damage in cellulose fibres with an adequate account of tensile strength, viscosity, copper number, methylene blue absorption, alkali solubility.

The modern views of Speakman and Astbury receive a full consideration in Section 9 and the chemical and mechanical treatment of wool while felting and fulling are described in the remaining section 10 which completes the first half of the work.

The second half of the book deals in great detail with the dyeing process and colloid chemistry of dyestuffs in 3 sections. (Nos. 11-13).

Two last sections concern soap, wetting, emulsifying and washing processes. It would be easy to criticise parts of this section but any criticism would not detract from the obvious value and general excellence of the work. Why mention crease-resistance of textiles (in 5 lines) under the heading " Treatment of fibres with emulsions " and then refer to Clayton and Amick instead of the original patents on the subject? The author is obviously more at home with the fundamentals of textile research than with the applications in the direction of the newer finishes.

In view of the high charge made for the work it might be worth while to issue the two main sections separately. One further point should be addressed to the publishers—it is exasperating for a reviewer to receive a book which is un-cut. It is quite unreadable until it is properly guillotined.

The method of indexing is unusual, and it takes more time to get at a particular original reference when authors' names only are inserted in the text together with an alphabetical list of authors' names and references at the end of each section. There appears to be no advantage whatever in this and no saving in type, since references are repeated two and three times.

There are very few misprints, $Na_2S_2O_4$ should read $Na_2S_2O_3$ on page 110.

This is a good book but too high in price, but every textile research director will want to add it to his library. Even if he does not, or perhaps cannot, read it himself, he must tell his staff to read it, for it cannot fail to be of benefit to himself and his Board of Directors in the long run. F.C.W.

The Alexandria Futures Market. By C. R. Barber. (Harlequin Press Co. Ltd., Manchester, pp. 78. Price 5/- net.)

This is a very useful addition to the descriptive literature regarding the marketing of cotton of which a good deal has appeared in recent years. It is well authenticated and well documented and covers the ground of the mysteries and the jargon of the Cotton Futures Market in Alexandria adequately and as simply as seems to be possible.

A point on p. 37 may be confusing to readers more familiar with the Liverpool market, where he speaks of " the basis " being 50 points *off* whereas in Liverpool the basis or difference between futures and spot is always in favour of spot ; inevitably so because the basis is the premium which the buyer is willing to pay for the right to select the cotton he wants. The explanation of the apparent paradox in Alexandria is that the spot quotation given is for August 3rd while the futures quotation is for November—different crop months.

That could not occur in Liverpool where there is always a future quotation for the actual current month on which as a matter of fact the spot price is based.

The book would have been still more useful if it had also described in the same detail the working of the spot market at Minet el Bassal. After all the spot market and the futures market are only two inseparable parts of one market, the market for cotton. J.A.T.

Textile Design and Colour: Elementary Weaves and Figured Fabrics. Fourth Edition. William Watson, F.T.I. Longmans Green & Co. Ltd. Price 21/- net.

This well-known text book was first published in 1912 and has now reached the fourth edition. It is a great tribute to the author that this is the case, especially when one finds that the text in the last edition is almost completely the same as in the first edition. The original book contained some 349 pages of text and illustrations and these are faithfully reproduced, with the exception of two changes only. One relates to Jacquard machines on page 210 ; the other is in connection with "Comparison of Cloth Structures," pages 126 to 129. Here the empirical formulae for calculating yarn diameters and estimating ends and picks per inch in possible structures, have been changed in expression but not in value. They produce the same answers as the original equations and are not so easily understood. The author has referred to other workers in this field, adopted their methods, but without adequate explanation of how the results are arrived at. For example, to state that the average float of a five-thread warp sateen is 2½ is certainly misleading. In the reviewer's opinion this change in the text has not been an improvement.

The new edition differs from the older ones in that the appendices have been enlarged. The first contains a very useful list of standard yarns, weaves, and fabrics covering 74 pages. The second is confined to rayon and covers another 50 pages. One feels that the 30 pages devoted to the systems of manufacturing rayon threads should not have been introduced in a book of this nature. It is just as unreasonable to expect chapters on the spinning of other materials in a book on textile design. The final pages deal with the properties of rayon yarns, standard rayon yarns, notes on weaving and the application of rayon in fabric construction.

This book, together with its companion volume, "Advanced Textile Design," has for many years been the foremost English work in fabric construction, and it will probably be many years before a more comprehensive work is produced. J.R.

Les Applications de la Lumiere de Wood et des Rayons Ultra-Violets dans les Industries Textile et Tinctoriale. par Maurice Déribéré. Les Editions Textile et Technique, Paris. 288 pp. Price 70 Francs.

In the few books which have appeared dealing with the ultra-violet fluorescence of materials as an aid in their identification, comparatively little space has been devoted to the textile aspect of the subject. The present work is a welcome addition, therefore, to the literature as it is devoted almost entirely to the application of ultra-violet light in the examination of textile materials.

Chapter I introduces some general remarks on fluorescence and gives a very brief description of some suitable ultra-violet apparatus including the so-called "Lampe Noire" to which most of the recorded results in the book refer. Although from the title of the book the author has set himself out to discuss the *application* of Wood's light, one feels that an amplification of this part of the chapter would have added to the usefulness of the work.

Chapter II gives some detailed information on the fluorescence of various natural and artificial fibres. It may be noted that the sub-title on page 47, viz. "Examination of Vegetable Fibres," should read "Examination of *other* Vegetable Fibres" for cotton has already been given detailed consideration earlier in this chapter. In the reference to the work of Weltzien on page 49, the first dyestuff mentioned as recommended by this author for distinguishing various types of rayon from natural silk and cotton is described as Brilliant Diamine Green G. This should be Brilliant *Dianil* Green G. The Colour Index under No. 710 (not 510) states that it is a mixture of Brilliant Dianil Blue 6G (not G) and a thiazol yellow. Correction is necessary in the table on the following page where this dyestuff is mentioned. With regard to Oxydianil Yellow and Direct Chloramine Yellow (p. 49), no reference is made to these brands under

No. 169 in the Colour Index as stated. It would seem desirable to have substituted "I.G." for the names of the makers of the dyestuffs as the firms mentioned no longer exist as separate entities.

Further chapters deal with the identification of stains due to a large variety of substances (including oils) and the appearance in ultra-violet light of vegetable extracts and tannins, organic dyestuff intermediates, etc.

Chapters VI-XII include descriptions of the appearance under the "Lampe Noire" of a large number of organic dyestuffs of different classes dyed on various fibres. It may be noted that very brief consideration is given to the behaviour of vat dyestuffs. An index to the lists of dyestuffs would have facilitated reference to them.

Succeeding chapters deal with the application of ultra-violet light in textile printing and in the detection of faults in printing. Mention is made of the so-called "Fantom-Fast" method of laundry marking. Other applications considered are the effect of ultra-violet rays on fabrics, the determination of the fastness to light of dyed materials and the measurement of the resistance of fabrics to water by the appearance of the fluorescence of various dyestuffs when the latter come into contact with water. A chapter is devoted to the fluorescence of substances used in finishing and a final chapter deals with fluorescent indicators and their application in the measurement of *p*H. A useful bibliography is included at the end of the book.

The text is notably free from typographical errors especially in view of the large number of dyestuff names that are listed. In future editions of the book the following small errors might be corrected. There is a mixture of type in the word "Graisse" (sub-heading on p. 60). On pages 188-193 among the lists of dyestuffs "Chloranthine" appears several times instead of "Chlorantine." The word is correctly rendered in the case of "Lilas Chlorantine BN" on p. 190.

The book is of undoubted interest to textile workers and especially to those engaged in textile testing. It seems essential, however, to bear in mind the limitations of this method of examination. The detailed cataloguing of the appearance in ultra-violet light of the large number of dyestuffs and other substances tends to suggest that the method has a precision to which it cannot legitimately lay claim. D.A.D.S.

ADDITIONS TO THE LIBRARY

Wool Production and Trade. 1936-37. A Supplement to Wool Intelligence Notes prepared in the Intelligence Branch of the Imperial Economic Committee. (London, 1937, Printed and Published for the Imperial Economic Committee by His Majesty's Stationery Office. 2/6 net.)

Illustrated Catalogue of Scientific Apparatus and Instruments for Educational Purposes. Issued by A. Gallenkamp & Co., Ltd., Technico House, 17-29 Sun Street, and 1-3 Clifton Street, Finsbury Square, London, E.C. 2.

A Selected List of References on the Chemical Testing of Textile Materials. (American Home Economics Association, 620 Mills Building, Washington, D.C. Price, 40 cents.)

Knitting Trades Directory, 1937-1938. Published by the Harlequin Press, Manchester. Price, 2/6.

This is a handy-sized volume providing a geographical guide to the industry as well as a sectional guide to yarns, fabrics, goods and machinery. Its increased size, particularly in the geographical section, is noteworthy as indicating the increasing development of the knitting industry.

T.

THE JOURNAL OF THE
TEXTILE INSTITUTE

Vol. XXVIII OCTOBER 1937 No. 10

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

Award of Institute Medal to Dr. F. W. Eurich

Further reference was made at the last meeting of Council to the Testimonial to Dr. F. W. Eurich, of Bradford, organised by Wool Trade representatives and by representatives of the Medical profession in Bradford. It was proposed that the Institute Medal should be given to Dr. Eurich and that at a forthcoming banquet, when the sums raised for the Testimonial would be presented, announcement should be made that the Institute Medal has been so awarded. It was agreed unanimously that this award should be announced. In support of the proposal a document was submitted embodying a description of the important and arduous researches carried out by Dr. Eurich whilst Bacteriologist for the Anthrax Investigation Board for Bradford and District. This document is reproduced in full hereunder and indicates clearly the scope and consequences of the work for which the Institute Medal is to be presented to Dr. Eurich. Announcement of the award was made at a banquet at the Midland Hotel, Bradford, on the 29th September, by Mr. Henry Binns, F.T.I., a Vice-President of the Institute. On the occasion cheques were presented to Dr. Eurich by Mr. J. H. Bates, F.T.I., President of the Bradford Chamber of Commerce and by Dr. Hayburn on behalf of the Medical profession. It has not yet been decided when the actual presentation of the Medal will be made but an announcement will be made in a later issue.

Dr. F. W. Eurich,
Awarded the Institute Medal.

THE ANTHRAX RESEARCH OF F. W. EURICH, M.D., Edin.

Honorary Consulting Physician, Royal Infirmary, Bradford; formerly Professor of Forensic Medicine, University of Leeds; and formerly Bacteriologist to the late Anthrax Investigation Board for Bradford and District.

When the Home Office published revised rules for the prevention of anthrax in the December of 1905, the Anthrax Investigation Board for Bradford and District was constituted. The Home Office co-operated with the Chamber of Commerce in constituting it, and Dr. Eurich was asked to conduct the bacteriological and medical work.

Dr. Eurich had a difficult and important problem to investigate. A case of wool-sorter's disease had been recorded in print for the first time in 1847, and the first post-mortem on a case was done in 1878. Dr. J. Henry Bell made the important identification of the disease with pulmonary anthrax the year after, in 1879, but Dr. Eurich had still the main task before him in 1905. In spite of attempts by manu-

facturers to make their wool safe to handle, the revision of adopted rules by a conference in 1884 between the sanitary committee and representatives of the manufacturers and wool-sorters of Bradford, and the statutory regulations of 1897, cases of anthrax were still alarmingly frequent and fatal.

A thorough knowledge of the anthrax disease was still urgently needed when the revised rules were published by the Home Office in 1905. The whole Bradford District was vitally concerned in the deadly menace to its workers by the dreaded "Bradford Disease," as anthrax was significantly called in France. Dr. Eurich, by securing the neccessary thorough knowledge of anthrax, by disclosing sound preventive measures, and by introducing improved treatment of the disease when contracted, has effectively reduced both the incidence and the fatality of the disease.

In securing these results Dr. Eurich had neither a trained staff nor a special laboratory. He did an enormous amount of work for a quite inadequate remuneration. The investigation involved the bacteriological examination of about 14,000 samples of wool and hair. It also involved making cultures of anthrax which were literally numbered in hundreds of thousands. The virulent nature of the anthrax bacillus was a constant and serious danger to the investigator.

Dr. Eurich's skilfully conducted investigation was largely single-handed, very laborious and highly dangerous; it was also genuinely pioneer. Though Dr. Bell had made the preliminary identification of wool-sorter's disease with pulmonary anthrax, Dr. Eurich was the first to cultivate the anthrax organisms from wool: he had been told that he would not find anthrax in the raw material. The enquiry also removed other mistaken ideas. It had been supposed, quite naturally, that dirty or offensive wools were the most dangerous, and perhaps the only dangerous materials. Dr. Eurich found that wools might be as dangerous when they were clean as when they were dirty. The infection of the raw materials through the blood of the animals produced persistent infectivity in both "clean" fleeces and wool which had been washed and scoured. The tenacious adherence of the blood serum to the material through the various processes, and the consequent retention of the anthrax organisms as a source of infection were exposed as significant items in the problem.

Before 1908, when the enquiry had proceeded for about three years, the distinguishing features of damaged fleeces from dead animals were unknown. The damaged and "fallen" fleeces taken from dead animals, which were removed by instruction, were judged by the lack-lustre appearance produced by long exposure after death. Since the bacillus of anthrax was found to die as putrefaction advances, the fleeces which presented this appearance most obviously were actually the least dangerous. Dr. Eurich also discovered that many varieties of wool or hair are liable to infection, and listed them roughly in order of danger, though the percentage of infected samples from countries where anthrax is endemic varies greatly in different years. Some of these varieties had been previously considered to be free from danger.

Experimental technique for studying anthrax was established by these researches. The nature of the anthrax bacillus, the way in which the material is infected, and the conditions under which the infection persists were discovered. Openers and sorters could be taught to look for the characteristics of dangerous material when the enquiry was thus successful.

Before this research dispelled errors and disclosed the facts various precautions, such as cleanliness and fanning off the dust, were taken, but the materials could not be actually disinfected by killing the anthrax bacilli without spoiling the spinning and dyeing properties of the wool. Dr. Eurich, in conjunction with Mr. Elmhirst Duckering, succeeded in killing all anthrax in any sample of wool or hair without detriment either to the material or to the workers. Formaldehyde was used, and a method of application was worked out to ensure effective penetration by the disinfectant and the destruction of the most resistent anthrax spores.

So far the cost of disinfection, though small, has prevented the sterilisation of all materials, but it is possible to sterilise them all. The cost may be still further reduced, or perfect safety may be secured by insisting on universal sterilisation through international co-operation.

Cases of anthrax will occur until all dangerous wool is sterilised, or effective precautions are taken in the country of origin. Dr. Eurich's work, however, has not only made complete safety possible, but has effectively reduced the incidence of the disease. His introduction of improved methods of treatment has also removed much of the terror when the disease is contracted by greatly increasing the percentage of cures.

Employment Bureau

Signs are not wanting that this activity of the Institute is making definite progress. Employers have given proof that they realise the value of the Employment Bureau services available and this should encourage those members unfortunate enough to be unemployed or who are desiring promotion to make use of the Bureau. In this issue of the *Journal* there are three advertisements of interest from the employment point of view. On page viii will be found an announcement of the first Harlow Fellowship to be awarded by the Bradford Technical College. On page xxiii the post of Head of the Sri Krishnarajendra

Silver Jubilee Technological Institute is advertised, whilst on page xxiv a new appointment in New Zealand is proposed. The attention of all members is called to these announcements. If any member of the Institute is successful in securing one of these posts it would be appreciated if intimation was sent to the Institute offices in Manchester. Any member desirous of using the services of the Employment Bureau should apply for Registration Forms to the General Secretary.

Employment Register

The following announcements are taken from entries in our Register of members whose services are on offer. Employers may obtain full particulars on application: —

No. 140—Young man, 29 years of age, desires position as Manager in Woollen Mill, able to take full control. At present employed by firm making all types of Fancy Woollen cloths—worsted warp / woollen weft, cotton warp / woollen weft, suitings, overcoatings, Ladies' dress and coating, etc. Conversant with designing and all processes from raw material to finished cloth, and with customers' requirements. Holder of City and Guilds Certs. and Diplomas. Excellent references. Experience in handling workpeople.

No. 168—Desires position as Manager or Weaving Manager or Master. City and Guilds Certificate for Cotton Weaving. Seventeen years' experience as Manager and Weaving Manager including all processes from the raw cotton to the finished piece goods. Age 45 years. Prepared to go abroad.

No. 169—B.Sc.Tech., age 23 years, desires position as Assistant Weaving Manager or Technologist. Speaks German and French. Position preferred abroad. Prizes for designing of woven fabrics.

No. 170—Young man, 26 years of age, requires responsible position in executive capacity with large textile house. B.Sc.Tech. Two years' experience of Textile Testing and 5 years as Shift Manager. Willing to go abroad.

No. 171—A.T.I., 32 years of age, desires position as Cotton Spinning Mill Manager or progressive position in Textiles. Full Tech. Cert. in Cotton Spinning. Nat. Cert. in Electrical Engineering. 5 years' experience in Electrical and Mechanical Engineering and 11 years in all departments of Cotton Spinning Mill.

No. 173—Young man, A.T.I., age 30, married, desires position as Chemist-dyer, assistant manager or responsible position in dyeworks. 12 years' practical experience rayon and associated fibres, knitted fabrics, yarn and hosiery, also expert knowledge of Azoic and Vat colours. City and Guilds Full Tech. Cert. in Dyeing Silk and Rayon ; Nottingham University College Diploma Textiles, present Examiner.

OBITUARY:

J. L. Michie, E. Midgley, W. Scott-Taggart, W. B. Wilson

It is not often, fortunately, that this Institute is deprived of the services of so many prominent members as during the past month. Professor Eber Midgley, Mr. W. Scott-Taggart and Mr. W. B. Wilson were all Foundation Members, the first two maintaining close interest in the administration of the Institute through its Council during the whole of their membership. Professor Midgley was continuously associated with the work of the Yorkshire Section of which he was at one time Chairman, and he was also a Vice-President. Mr. W. Scott-Taggart in the early days of the Institute acted as Secretary for a short time. Mr. J. L. Michie, as also were Professor Midgley and Mr. Scott-Taggart, was a fellow of the Institute, and served on the Scottish Section Committee, giving willing service to the Institute's interests in Scotland. Mr. W. B. Wilson, though he did not serve on any Institute Committee, attended its meetings and Conferences and supported the work generally in other ways. All four of these members will be missed and the Institute is the poorer by their loss.

TEXTILE INSTITUTE PRIZE DISTRIBUTION

The President, Mr. John Crompton, presided over a record attendance at the annual distribution of prizes in connection with the Institute's Competitions in yarns and fabrics, which took place on Saturday, 9th October. He was supported on the platform by Mr. Frank Pick, Chairman of the Board of Trade Council on Art and Industry, who distributed the prizes, Sir John Grey, Sir T. D. Barlow, and Mr. W. W. L. Lishman, Hon Treasurer.

The President said that whether a student won a prize or not, the putting together of an album in the main competition was something very practical and a testimonial of a character that any prospective employer was not likely to turn aside. Out of many applicants the one able to show an album, on that merit alone, would be more likely to obtain the situation desired.

They were delighted to have on the platform Mr. Frank Pick whose interest in the development and application of art was such that he had willingly made a special journey from London for this occasion. Mr. Crompton said he was delighted to see that the Vice-Chancellor of Oxford University had recognised that students between leaving school and entering the University profited by twelve months' practical experience in industry. He heartily agreed. The experience thus obtained from industry would later stand them in good stead. If the Master of Balliol could get others to agree with him, he felt sure that the textile industry would be delighted, and would assist him. He then called on Mr. Pick to address those present.

Mr. Pick said that after he had accepted the invitation to come to Manchester he carefully studied a document forwarded to him by the General Secretary. That document was the Prospectus of the Textile Institute Competitions for 1937. He saw in the document that they had received gifts for the prize funds of these competitions. It was so rare that money was given to a useful living purpose ; he was glad. More often money was given to charity. He suggested that charity had its defects. He rather thought that charity bred the need for charity. It was not uncommon to see notification in the press that bequests had been made to charity but how rarely did one see that a bequest had been made to encourage Art. Still more rare was it that such a gift should be made during the life-time of the donor. But Art, the things we saw, occupied a big proportion of our lives, perhaps a fifth or even a fourth. Art released that creative spirit now apparently confined to mankind. It surely merited every consideration and in his view every encouragement.

Again considering the Prospectus, the second thought he had was whether Competitions were a good thing. He had come to dislike competitions and to regard them as artificial, often divorced from realities and practical problems of life. Would it not be better, asked Mr. Pick, to award prizes for achieved success in the ordinary walks of life ; a crown given for labour carried on in the social structure at large. But he had considered carefully the conditions under which these Competitions were conducted and he had concluded that they were such as to approach very closely to the conditions he felt were desirable. The task of adjudication had been a serious one and so far as he could see had been as seriously and successfully carried out. All who had entered must have gained something out of it rather than from it. Something of the joy of creation could be theirs even if they had not won a prize.

Mr. Pick said that he observed also from the Prospectus that the elements of judgment had been carefully thought out and set down therein. This he found most intriguing. For " Cloth Structure and Fitness for Purpose " 25 per cent. marks were given. Those were marks for a good cloth. This was the highest award of marks for a single element of judgment be it noted. Then for " Use of Colour " 20 per cent. marks were given and 20 per cent. for " Originality of Design." This meant a total of 40 per cent. for " Appearance." He wondered if it were good to strive so much for originality: was it not better to strive for improvement. For " Commercial Value " in this scale of judgments, he

continued, 20 per cent. marks were to be awarded and for "Costings" 15 per cent.; a total of 35 per cent. on economic grounds. This was a modesty he had not expected from the manufacturer or the merchant. In his view this was a noteworthy and praiseworthy basis for adjudication and one that might well receive more general adoption in Manchester for all purposes. Yet be it noted, all the elements in the scheme ran together, success in part could not win a prize. Herein was a lesson for the School of Art, said Mr. Pick, and he commended the need to combine all these elements of judgment to their attention. They must bear in mind that 35 per cent. of economic factors when deciding upon the usefulness and serviceability of the work their Schools turned out. But, continued the speaker, there was another element unrecorded in those conditions, in that scheme of adjudication. It was that of the times in which these textiles were being produced. It was the textiles of to-day that they were dealing with—textiles in a given social setting. There was to be no imitation of or reflection from the past that had gone; the flowered silks of a time more exquisite, the velvets and brocades of the Renaissance, and homespuns of a rustic mode of life. History was indeed written in cloth. He had been looking at a pattern book covering the past 150 years and herein he saw how history had affected design. There times of opulence and stringency, the impact of the gorgeous east, joy and mourning, peace and war, were all reflected. Social geography in cloth was also evidenced by the Manchester cottons for every market, revealing prejudices, customs, taboos and religions.

Those present, continued Mr. Pick, were writing history of their own time in cloth. What sort of history was it to be? Thought of in this way values were transformed. Sincerity and truth were of greater importance than originality. What they wanted to arrive at was what was beauty now, not a version of someone's contribution to the past. They had interfered with nature and thus taken upon themselves the responsibility of proving that that interference was right. We wanted textiles to express the civilisation in which we lived to-day. If they truly expressed their own aims, opportunities, and strivings towards beauty then they might create textiles worthy of themselves and the society in which they lived.

He hoped that with their prizes they might take away the thought of the importance of their calling as recorders of current social aim and purpose at its best, as creators of that beauty which could alone redeem our civilisation in those ugly cities and towns which our ancestors had built and bequeathed to us.

Sir Thomas Barlow, who had distributed the prizes in 1936, proposing a vote of thanks to Mr. Pick said that one did get rather discouraged on this question of design as applied to textiles and other forms of aesthetic activity, and one wondered where it was going to end and whether they were going to get anywhere. Although progress was slow he believed that real progress was being made. Mr. Pick had raised his own doubts about competitions, but he, Sir Thomas, thought although they must be described as a necessary evil, he still hoped that these competitions would continue to flourish. He was sure they had been of real value to the trade.

Sir John Grey seconded and said it had been a great pleasure to listen to Mr. Pick. The Board of Trade was not too willing to give anything away but they had done a great deal for them by asking Mr. Pick to come to Manchester. He thought that everything that was beautiful in art and design lived. It might change in form and method of application, but the idea behind every beautiful design never died. He did not think competitions were an evil or should be abolished. They were a trial and caused not infrequently, pain, but they had a measure of value and he did not know what could be substituted for them or what would be fairer all round. It was very encouraging to see the students there. He believed there was going to be more and more opportunity for men and women of ability and talent in the textile industry than there had been in the past.

The motion being carried, Mr. Pick, in reply, said that in this matter of competitions they could not shut their eyes to the fact that the competitive spirit was very much that of life. No one could get rid of it, and they wanted more of it than less.

Mr. Pick then presented prizes to successful entrants of whom the following is a complete list:—

ANNUAL COMPETITIONS, 1937: AWARDS

(A) COMPETITION: WOVEN FABRICS

First Prize (£25 & Certificate)	L. A. Smith (Colne Municipal Technical School).
Second Prize (£15 & Certificate)	J. Baker (Bolton Municipal Technical College).
Third Prize (£10 & Certificate)	C. Evans (Colne Municipal Technical School).
Prizes of £4 each	F. Smith (Keighley Technical College).
	R. Haworth (Accrington School of Arts & Crafts).
	J. Wells (Salford Royal Technical College).
	Harold Whitaker (Bradford Technical College).
	F. Wilmore (Nelson Municipal Technical School).

(B) COMPETITION: YARNS

CLASS I: NOVEL FOLDED YARNS	
First Prize (£5)	C. H. D. Spencer (Bradford Technical College).
Second Prize (£3)	Harry Whitaker (Bradford Technical College).
CLASS II: NOVEL SINGLE YARNS	
First Prize (£3)	Harry Whitaker (Bradford Technical College).
Second Prize (£2)	T. E. McGrew (Blackburn Municipal Technical College).

(C) COMPETITION: SPECIAL WOVEN FABRIC

Equal £4 Prizes	F. Walsh (Accrington School of Arts and Crafts).
	H. Bancroft (Manchester College of Technology).
£3 Prize...	C. Nutter (Manchester College of Technology).
Equal £2 Prizes	R. Goddard (Burnley Municipal College).
	M. Thompson (Colne Municipal Technical School).

(D) COMPETITION: WOVEN FABRIC

First Prize (£3)	K. Nuttall (Burnley Municipal College).
Second Prize (£2)	J. M. H. Grey (Burnley Municipal College).
Prizes of £1 each	H. Manning (Burnley Municipal College).
	O. Whitaker (Burnley Municipal College).
	J. Barlow (Bury Municipal Technical College).
	W. A. Dyson (Nelson Municipal Technical School).
	W. Gray (Nelson Municipal Technical School).

(E) COMPETITION: KNITTED FABRIC

First Prize (£5)	L. H. Kirkham (Nottingham University College).
Second Prize (£3)	Miss E. M. Lynam (Nottingham Univ. College).
Third Prize (£2)	W. C. Russell (Nottingham University College).
Prizes of £1 each	K. Dooley (Nottingham University College).
	Miss E. M. Freund (Nottingham Univ. College).
	Miss E. M. Littlejohn (Nottingham Univ. Coll.).

(F) COMPETITION: DESIGNS FOR PRINTED FABRICS

CLASS I: DESIGNS FOR DRESS MATERIALS	
First Prize (£7)	Wm. Parker, 16 Kings Road, Old Trafford, Manchester.
Second Prize (£5)	G. F. Ainscow, 17 St. Albans Street, Rochdale.
Third Prize (£3)	E. Sharp, 21 Howden Road, Hr. Blackley, M/cr, 9
CLASS II: FURNISHING FABRIC	
First Prize (£5)	A. R. Clough, 40 Old Moat Lane, Withington, Manchester.
Second Prize (£3)	Miss M. Simmons, 354 City Road, Old Trafford, Manchester.
Third Prize (£2)	S. Richardson, 12 Percival Street, Longsight, Manchester.

(G) COMPETITION : SPECIAL WOVEN FABRIC (WORSTED)

CLASS I : MEN'S WEAR

First Prize (£3)	F. R. Whitwam (Halifax Municipal Tech. College).
Second Prize (£2)	J. Hirst (Bradford Technical College).
Third Prize (£1)	Harold Whitaker (Bradford Technical College).

CLASS II : WOMEN'S WEAR

First Prize (£3)	J. Thomas (Bradford Technical College).
Second Prize (£2)	G. B. Chaffe (Bradford Technical College).
Third Prizes (£1 each)... ...	J. Hirst (Bradford Technical College).
	W. Leng (Halifax Municipal Technical College).

(H) COMPETITION : WOVEN FABRIC (WORSTED)

First Prize (£3)	J. S. Binns (Keighley Technical College).
Second Prize (£2)	E. V. Jarman (Keighley Technical College).
Prizes of £1 each	J. Hirst (Bradford Technical College).
	R. Scholfield (Bradford Technical College).

The following is the Textiles and Designs Committees' Report on the 1937 Competitions.

TEXTILES & DESIGNS COMMITTEE : REPORT ON 1937 COMPETITIONS

The Committee is pleased to be able to record not only an increase in the numbers of entrants for the various Competitions under its control but a definite all-round improvement in standard of achievement. In consequence, the task of adjudication proved more difficult and, the general level being higher, final placing in strict order of merit required close attention to every phase of the work. The Committee is satisfied that increased interest, by students and schools, in the structure, design and colour of fabrics, is being stimulated to an extent which more than justifies the efforts, and the work provides training for prospective young designers.

In Competitions A, C, & D, the variety of fabrics sent in covers a wide range of manufacture, and reflects credit upon the textile Colleges where the specimens have been produced.

It is noted with appreciation that the practical work of the schools, as demonstrated by the woven samples, is more up to date ; and co-operation with the dyer and finisher has enabled the student to submit the fabric in a state ready for the user.

The Committee has noticed the growing tendency to display portions of clothing fabrics on drawn, painted, or cut-out figures. Whilst there is every desire to encourage neat and artistic presentation of woven samples on the display sheets it has been decided that pictures or models may not be used. Lengths of fabric or articles to display the specific properties or purpose of a fabric may be submitted separately from the Competition album. Calculations of yarn costs and quantities to ascertain price per yard are more satisfactory than formerly, and it is hoped this feature will continue to receive adequate attention. In Competition C, both in the cotton and rayon sections, some splendid qualities of dress and soft furnishing fabrics have been submitted.

Competition B. The Committee consider that entries, in the light of the addition of a new competition—in Novel Single Yarns—have not yet reached a satisfactory level. It is intended, however, to persist with the Single Yarn Competition in the hope that in the course of a year or two it may prove more attractive. The general standard of production in both classes of the competition has been maintained, whilst certain modifications have been made in the conditions to indicate clearly what is required in the Single Yarn Competition.

Competition E : Knitted Fabric. The standard of the exhibits is very much higher than last year, and the Committee is glad to note a marked increase of entries where the motivisation is structural.

Competition F : Designs for Printed Fabrics ; I, Dress Fabrics ; II, Furnishing Fabrics : The use of colour, particularly in Class II, Furnishing Fabrics, can be considerably improved.

Competitions G and H : In the new competition for worsted fabric for (I) Men's wear, (II) Women's wear, made available by the recent Beanland bequest, a very good start has been made. The Committee hope that a similar prize scheme for woollen fabrics will ere long be financed by a generous donor.

Midlands Section

THE DEVELOPMENT OF "FIBRO" AND "FIBRO"-WOOL YARNS.

Abstract of Lecture given by Mr. W. Hardacre (Courtaulds, Ltd.) to the Midlands Section of the Textile Institute at Leicester on the 21st January, 1937.

"Fibro" is the registered name for Messrs. Courtaulds' staple fibre. It is not a waste or by-product but is one of the finest products of their rayon factories. It is a new and special fibre that is finding its own place in textiles as a new fibre rather than as a substitute for the older fibres. In suitable

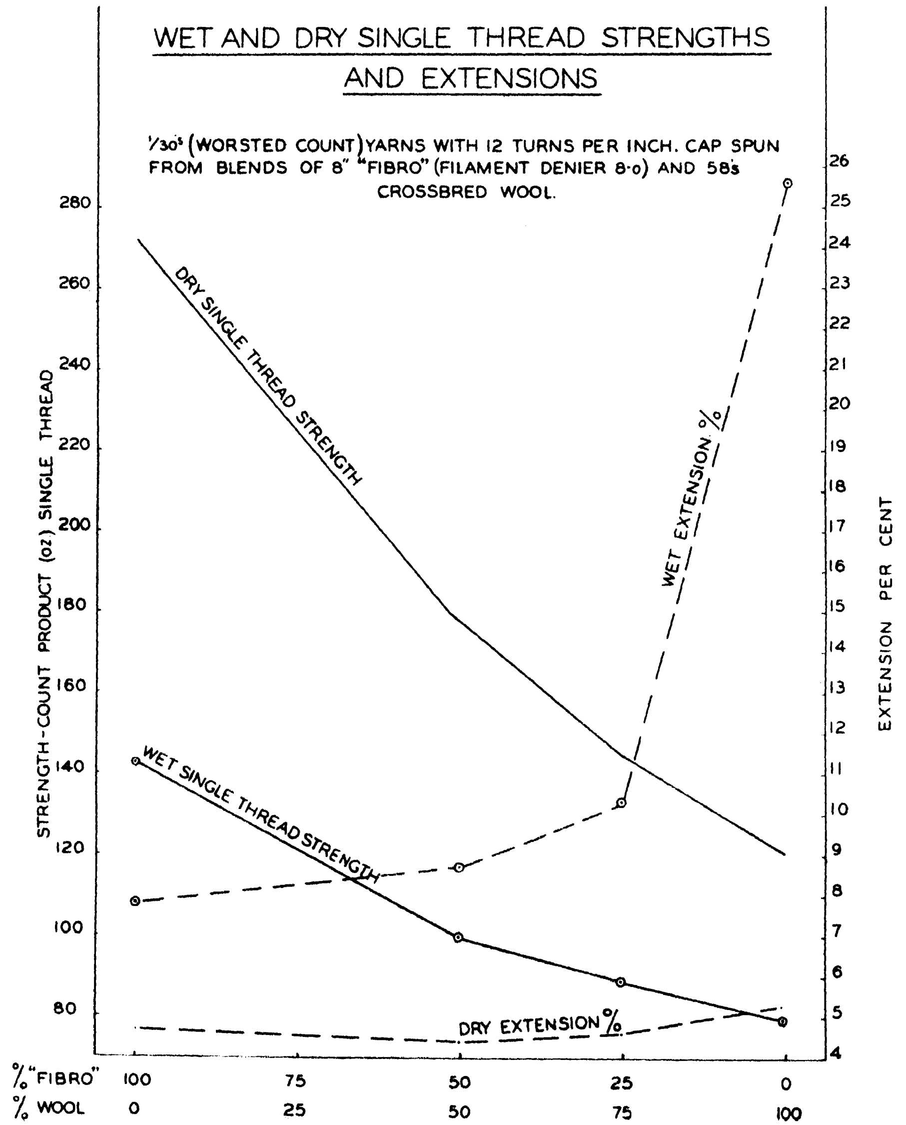


Fig. 1

staples and deniers " Fibro " is being blended with wool and the use of both fibres is being extended by the creation of yarns and cloths of new types.

In order to give direction to the increasing use of " Fibro " in the worsted industry, Messrs. Courtaulds have nearing completion a demonstration factory at Bradford, Yorks., for the carding, combing and spinning of " Fibro " and " Fibro "-wool blends. This factory will assist firms who are seeking to introduce " Fibro " into their products.

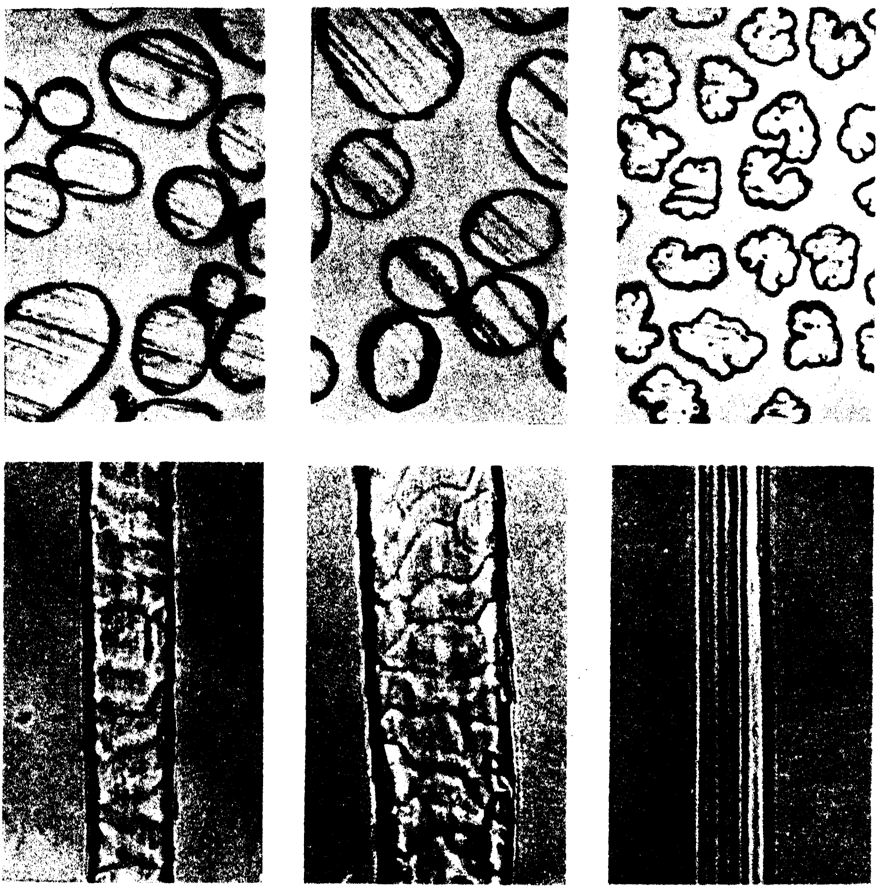


Fig. 2

80's quality Merino (×500)	58's quality Crossbred (×500)	3.0 Denier Bright "Fibro" (×500)

Some of the results of experiments on " Fibro " yarns and " Fibro "-wool blends have appeared in the " Processing of ' Fibro ' on Standard Worsted Machinery " (1). In this paper the effects on yarn strength and extension at break of changes of staple from 3″-6″ and denier from 1·5/fil to 4·5/fil were illustrated. Blends of " Fibro," 4″, 3·0 denier, and 64's merino wool were examined at different twists. Since that time the range of materials examined has been extended to include longer and coarser " Fibro " and lower qualities of wool. Some of the more interesting results are noted here.

Staple Length. Increasing the staple length up to 8″ has indicated that only a small increase of dry strength is gained. There is no evidence of an increase of wet strength, and the extension at break decreases.

Denier. Other things being equal yarns spun from filaments of fine denier are stronger than yarns spun from coarser ones. The tensile properties of "Fibro" yarns are much more sensitive to changes of denier than staple. In the case of a 1/30s worsted yarn of 11 turns per inch, 4″ staple, decreasing the denier from 4·5/fil to 1·5/fil caused the lea strength product to increase 110 per cent. In the case of a 1/30s (worsted count) worsted spun "Fibro" yarn

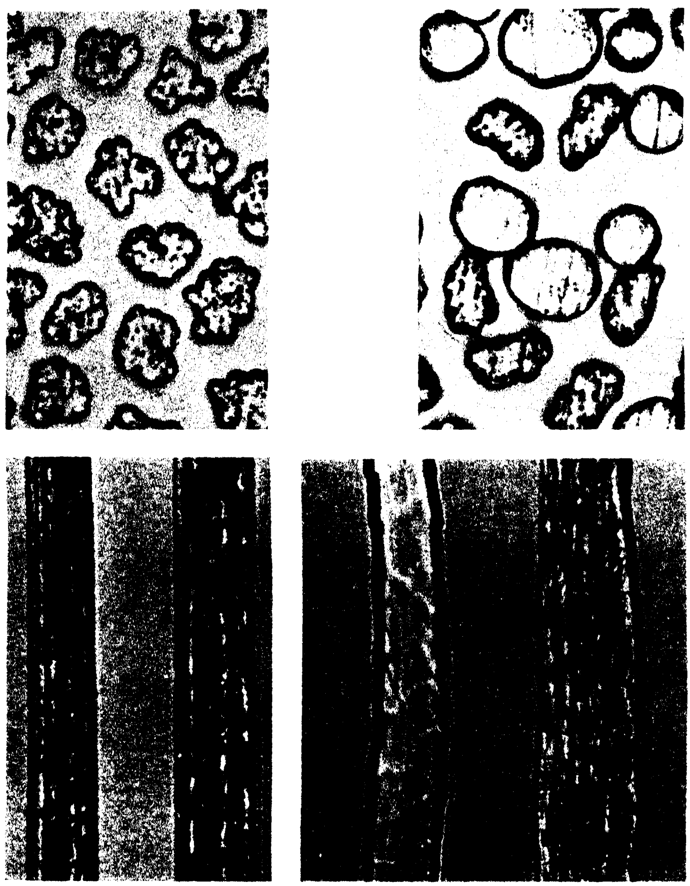


Fig. 3

3.0 denier
Matt "Fibro"

50% Matt "Fibro"
4″ Staple 3.0 denier
50% 80's Quality Merino

($\times 500$)

of 8″ staple, spun to maximum strength, changing the denier from 8/fil to 4·5/fil caused the yarn strength to increase 30 per cent. There is an indication that yarns spun to maximum strength are less sensitive to changes of denier than yarns of lower twist.

Blends of "Fibro" and Wool. For blending with wool and similar fibres, "Fibro" is now available in a range of staples and deniers so that a filament can be chosen that has very nearly the same staple as the wool. "Fibro"

will generally be finer than the wool with which it is being blended. For example for blending with a 64's merino, "Fibro" of 4″ staple, and 3·0 or 4·5 den./fil, will be suitable; whether the finer or coarser denier is used will depend, among other things, on the handle required in the yarn. For a 58's, "Fibro" of 6″ or 8″ staple, 4·5 denier, and for a 46's, "Fibro" of 8″ staple, 8·0 denier would be chosen.

Fig. 3 shows the cross section of the fibres in a blend of "Fibro," 4″, 3·0 denier, matt and 80's merino wool. The difference of fineness between them is small and the fibres are suitable for blending.

The general effect of increasing the "Fibro" content of a "Fibro"-wool blend is to increase the count to which it can be spun. By keeping the count of yarn constant the dry strength of the yarn is increased with increasing "Fibro" content. In all cases examined the wet strength of the 100 per cent. "Fibro" yarn is greater than the dry strength of a wool yarn spun from wool of similar length and fineness.

The dry extension at break of "Fibro"-wool blends is not sensitive to changes of proportion in the blend.

The wet extension at break of these blends is practically constant between the range of 100 per cent. "Fibro" and 50 per cent. "Fibro"/50 per cent. wool. When the wool content exceeds 50 per cent. the extension at break of the yarn approaches that of the 100 per cent. wool yarn.

Fig. 1 is based on the results of tests made on yarns spun from "Fibro," 8″ staple, 8·0 denier and 58's crossbred wool (which has approximately the same denier), spun to 12 turns per inch. This graph shows the effect on yarn properties described above, which are characteristic of the blending of coarse "Fibro" and wools.

The accompanying photo-micrographs (Fig. 2) show longitudinal views and cross sections of "Fibro" of different deniers and wool of various qualities, and give some idea of the relative diameters of the two fibres of different deniers and qualities. Table No. 1 has been drawn up to give the approximate filament deniers of several wool qualities so that the wool required for blending with a particular type of "Fibro" can be chosen.

TABLE I.

Material	Mean hair weight per centimetre	Corresponding Filament Denier
"Fibro"	0·00167	1·5
"Fibro"	0·00333	3·0
"Fibro"	0·00500	4·5
80's Merino Wool	0·00416	3·7 approx.
70's " "	0·00481	4·3 "
64's " "	0·00557	5·0 "
60's " "	0·00656	5·9 "
58's Crossbred Wool	0·00832	7·5 "
50's " "	0·01171	10·5 "
48's " "	0·01604	14·4 "
40's " "	0·01729	15·6 "

The author desires to acknowledge the assistance of Mr. J. A. Kirby, M.Sc. Tech., in the preparation of the data, and also Mr. Hegan, B.Sc., A.I.C., for the photo-micrographs.

(1). *J. Text. Inst.*, 1936, **27**, P315-326.

THE MEASUREMENT OF FINENESS OF WOOL

The International Wool Textile Organisation Standard Method and the Zeiss Lanameter.

Dr. E. FRANZ.

In a previous paper* the advantages and shortcomings of the various methods of measuring wool fineness were discussed in some detail. The conclusion reached was that the only suitable method consisted of the measurement of the magnified images of a large number of fibres with a view to obtaining an accurate expression, not only for the mean thickness, but also for the distribution by means of the histogram of the various thicknesses.

Various other laboratories, e.g. those in England, Hungary and Italy, had reached the same conclusion independently. Consequently the Scientific Sub-Committee of the International Wool Conference, after the various possibilities had been thoroughly investigated, decided to adopt this method. The results are to be found in the resolutions of the Scientific Sub-Committee which were passed partly at the meeting in Leipzig, and partly at Warsaw, and unanimously adopted by the full assembly in Warsaw.

RESUMÉ.

The following international regulations for the measurement of wool fineness were unanimously adopted by the Research Committee of the International Wool Federation and laid before the Wool Conference.

1. Selection and Preparation of the Sample.

(*a*) *For Tops.* At a minimum of four places in the top under consideration, separated by distances greater than the length of the longest fibre, 2 mm. sections are cut at right angles across the sliver. The sections must extend over the entire cross section of the top sample. The fragments of fibres thus obtained are shaken up in a small flask with cedarwood oil (thickened for optical reasons), and stirred up with a glass rod. Without allowing sedimentation, one or more drops which adhere to the glass rod are placed on a slide and spread out for measurement.

(*b*) *For Yarn.* If the size of the sample permits, 100 metres of yarn are wound off on a 1 metre reel. The resultant hank is then cut at four places in 2 mm. sections, as for the top. The 2 mm. cut lengths are then prepared for measurement as above. With smaller samples, care must be taken to cut the 2 mm. sections in at least 20 different places, if possible at a distance from each other exceeding the length of the longest fibre.

2. Measuring Apparatus.

For the determination of fibre diameter a projected image at 500 x magnification is employed. It is recommended that as strong an objective and as weak an eyepiece as possible be employed. (In the Doehner apparatus a Reichert objective No. 5 is used in conjunction with eyepiece 8 x of the same make.) The distance between screen and eyepiece is not definitely prescribed, depending as it does upon the magnification and the lens system in use. Calibration should be carried out as often as possible by means of an object micrometer, particularly when measurements are being made for purposes of arbitration.

3. Measurement Procedure.

The enlarged images of the fibres are measured in turn. The μ values are read to 1μ and arranged in groups of 2μ. The group limits are 9-11μ, 11-13μ,

* Dr. E. Franz and Dr. H. Mendrzyk. The Determination of fineness length and crimp of combed wool, and the numerical classification of German types of top. *Melliand Textilbericht*, 1934, XV, 194, 242, 289.

LIST OF MEMBERS, 1938 (*see over*).

INSTITUTE MEETINGS

Tuesday	2nd November	*Manchester*—3 p.m. Meeting of Publications Committee, at Institute.
Wednesday	3rd November	*Manchester*—2.45 p.m. Meeting of Diplomas Committee, at Institute.
Wednesday	17th November	*Manchester*—3 p.m. Meeting of Council, preceded by Finance and General Purposes Committee.

LANCASHIRE SECTION

Thursday	11th November	*Oldham*—7.30 p.m. Joint Meeting with the Oldham Technical Association. Lecture: "The Textile Institute's Scheme for Standardisation in Textiles," by Mr. F. P. Slater, M.C., M.Sc., M.A., F.T.I., at Technical College.
Wednesday	24th November	*Bolton*—7.30 p.m. Lecture: "Recent Developments in Cotton and Staple Rayon Spinning Machinery," by Mr. Harold Hill, A.M.I.M.E., F.T.I., at Technical College.

MIDLANDS SECTION

Wednesday	17th November	Visit to Locomotive Works of London, Midland & Scottish Railway Co., Derby.

OTHER ORGANISATIONS

Batley and District Textile Society—

Thursday	4th November	*Batley*—7.30 p.m. Lecture: "Recent Application of Lighting in Textile Mills," by Mr. J. W. Howell, D.L.C., A.M.I.E.E., at Technical College.
Thursday	18th November	7.15 p.m. Visit to Messrs. Charles Walker & Co., Ltd., Leeds.

Blackburn Textile Society—

Friday	5th November	Lecture: "The Weaving of High-grade Fabrics," by Mr. George Harris.
Friday	19th November	Lecture: "The Dyeing and Finishing of Rayon Piece Goods," by Mr. C. P. Atkinson.

Bolton and District Managers, Carders and Overlookers Association—

Friday	12th November	*Bolton*—8 p.m. Lecture: "Banks and Banking," by Mr. H. K. Daniel, at Saddle Hotel.
Friday	19th November	*Rochdale*—8 p.m. Lecture: "Winding and Doubling," by Mr. C. Holliday, at White Swan Hotel.
Saturday	20th November	Visit to Platt Bros. Ltd., Oldham.

Bradford Textile Society—

Monday	1st November	*Bradford*—7.30 p.m. Lecture: "X-Rays in Industry," by Dr. L. Pickup, M.Sc., Ph.D., at Midland Hotel.
Wednesday	3rd November	Evening visit to Messrs. Hepworth & Grandage, Ltd., Bradford.
Monday	15th November	*Bradford*—7.30 p.m. Lecture: "Shrinkage in Wool Fabrics," by Professor A. T. King, B.Sc., F.I.C., at Midland Hotel.
Monday	29th November	*Bradford*—7.30 p.m. Lecture: "Speciality Fibres, Synthetic and Vegetable," by Mr. H. Roberts, at Midland Hotel.

Burnley Textile Society—

Tuesday	9th November	*Burnley*—7.30 p.m. Lecture: "Improvements in Weaving Mechanisms," by J. Andrew, at Mechanics' Institute.
Saturday	13th November	Visit to Leyland Motor Works.
Tuesday	23rd November	*Burnley*—7.30 p.m. Lecture: "Sizing Materials," by Mr. T. Hilton, at Municipal College.

Colne and District Textile Society.

Saturday	6th November	Visit to British Bemberg Ltd., Doncaster.
Friday	26th November	*Barnoldswick*—7.30 p.m. Film: "The Production of Viscose Yarns," shown by North British Rayon Ltd., at Co-operative Guild Room.

Cumberland Textile Society—

Thursday	11th November	*Carlisle*—7.30 p.m. Lecture: "Research in Industry, Wool Textile Research," by Mr. B. H. Wilsdon, at Technical School.

Derby Textile Society—

Wednesday	3rd November	*Derby*—7.30 p.m. Lecture: "Fabrics from the Launderers Point of View," by Mr. J. N. Vowler, at Technical College.
Thursday	25th November	Visit to L. M. & S. Railway Co.'s Research Laboratory.

Halifax Textile Society—

Saturdays	6th and 13th November	Visit to *Yorkshire Observer*, Bradford.
Monday	8th November	Lecture Visit to the General Post Office, Halifax.
Monday	22nd November	*Halifax*—Lecture: "Eulan Moth-Proofing Methods," by Mr. C. O. Clark, F.T.I., at White Swan Hotel.

Haslingden District Textile Society—

Thursday	4th November	*Haslingden*—7.45 p.m.—Lecture: "Textile By-Products," by Mr. H. Hardy, A.T.I., at Grammar School.
Thursday	18th November	*Haslingden*—7.45 p.m. Lecture: "Modern Machinery for Preparing and Spinning Cotton Waste," by Mr. A. J. Drabble, at Grammar School
Saturday	20th November	Visit to New Showrooms of Messrs. Platt Bros. & Co. Ltd., Oldham

Huddersfield Textile Society—

Monday	1st November	*Huddersfield*—Lecture: "The Chemical Constitution of Wool: Modification of the Wool Fibre by Chemical Action," by Mr. H. Phillips, D.Sc., F.I.C.
Monday	15th November	*Huddersfield*—Lecture: "The Physical Properties of the Wool Fibre," by Mr. G. R. Stanbury, B.Sc., F.Inst.P., A.R.C.S.
Monday	29th November	*Huddersfield*—Lecture: "Statistical Measurement of Variability in Textile Products," by Mr. H. E. Daniels, M.A. (Edin.), B.A. (Cantab.).

Keighley Textile Society—

Monday	1st November	*Keighley*—7.30 p.m. Lecture: "Control of Variability in Textile Processes," by Mr. B. H. Wilsdon, M.A., B.Sc., at Kiosk Cafe.
Saturday	6th November	Visit to Wool Industries Research Association, Leeds.
Saturday	20th November	Visit to Messrs. Hailwood & Ackroyd, Ltd., Morley.

Leicester Textile Society—

Wednesday	17th November	Visit to Loughborough College.
Friday	26th November	*Leicester*—7.30 p.m. Lecture: "Some Experiences of Industrial Russia," by Mr. W. Samuel.

Morley and District Textile Society—

Tuesday	2nd November	*Morley*—Lecture: "Woollen Yarn Manufacture," by Mr. W. Conyers, at Technical Institute.
Saturday	6th November	Visit to Messrs. Wilson & Co., Barnsley, Ltd.
Tuesday	30th November	*Morley*—Lecture: "Some Essential Principles and Practices in Industry To-day," by Mr. J. Halstead, at Technical Institute.

Oldham Technical Association—

Thursday	11th November	*Oldham*—7.30 p.m. Lecture: "The Textile Institute's Scheme for Standardisation in Textiles," by Mr. F. P. Slater, M.C., M.Sc., M.A., F.T.I., at Technical College. Joint meeting with Textile Institute, Lancashire Section.
Tuesday	23rd November	*Oldham*—7.30 p.m. Film: "Oxygen Cutting, Metal Spraying and Surface Hardening," by The British Oxygen Co. Ltd., at Technical College.

Shipley Textile Society—

Thursday	18th November	Visit to Kirkstall Power Station.
Monday	22nd November	*Shipley*—7.30 p.m. Lecture: "The Training of Weavers, Some Suggestions," by Mr. N. C. Gee, A.T.I., at Technical Institute.

Todmorden Textile Society—

Saturday	20th November	Visit to works of Messrs. Platt Bros. Ltd., Oldham.

Guild of Calico Printers', Bleachers', Dyers' and Finishers' Foremen—

Friday	12th November	*Bolton*—7.30 p.m. Lecture: "Art and Printing," by Mr. F. Heyes, at Railway Hotel.
Saturday	13th November	*Manchester*—6 p.m. Lecture: "The Dyeing of Staple Fibre and Staple Fibre Unions," by Mr. J. G. Grundy, at Thatched House Hotel.

LIST OF MEMBERS, 1938.

To all Members,

A copy of the List of Members has now been circulated to every member. I should be glad if members would peruse the entry recorded on their own behalf and forward any amendment or addition required in this connection.

Notifications for inclusion in the 1938 issue of the List should reach me not later than 31st March, 1938.

HUGH L. ROBINSON,

General Secretary.

13-15μ, etc., with the group means 10μ, 12μ, 14μ, etc., and values falling between two groups are assigned to the lower of the two.

4. Treatment of Results.

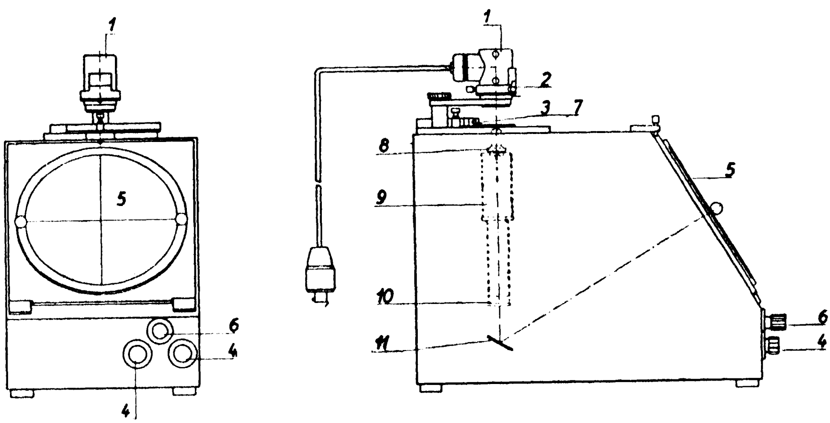
The mean is calculated from the values of the fineness thus obtained. Mean fineness is not stated in μ, but the μ value is converted into the equivalent metric fineness number by the formula:—

$$N_m = 4.10^6 / \pi d^2 S$$

(N_m = metric number in mg.; d = diameter in μ; S = specific gravity) where the specific gravity of wool is taken as 1·31.

This formula was adopted on practical grounds in place of the complicated theoretical formula based on the mean squares of the individual values.

In all cases, a reproduction of the individual measurements in the form of a frequency curve is essential. The drawing of a frequency curve follows as a natural consequence of the establishment of group widths and group limits, and transparent paper is used so that several curves can be laid one over the other for comparison. The curve is drawn in step form.



The Zeiss Lanameter

5. Number of Fibres to be Measured.

This depends upon the quality of the wool. As a general rule for merinos, two slides of 200 fibres each should be measured. If the mean values of these two vary by no more than 1μ then the test may be considered complete, and the grand mean calculated from the individual values. If the difference is greater than 1μ then further samples of 200 fibres should be measured.*

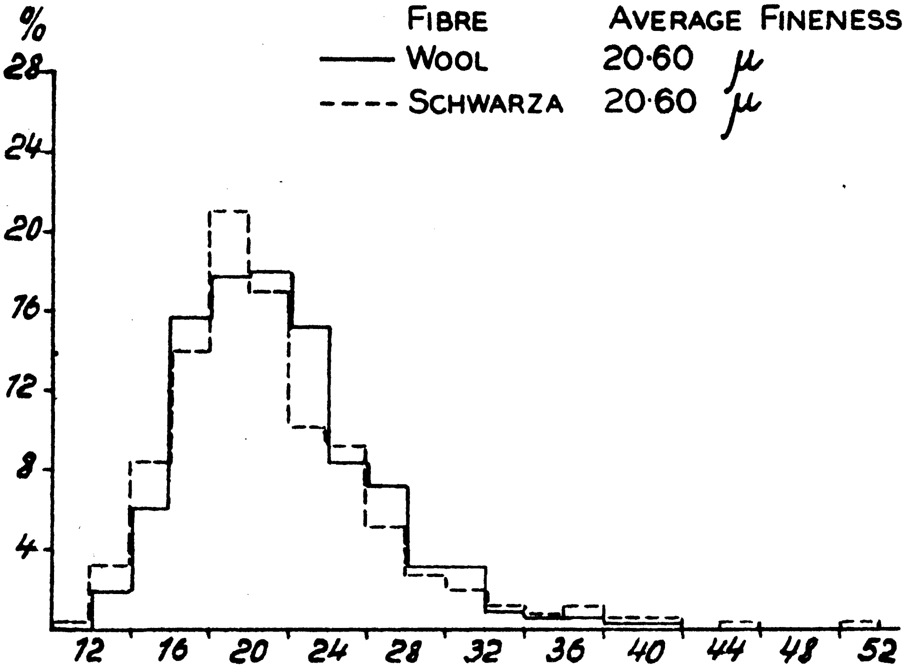
For crossbreds, similarly, 2 x 300 fibres should be measured. If the means of these two agree within 1·5μ (inclusive) then the test is sufficient; if not, further samples of 300 fibres should be measured. As a boundary line between merino and crossbred, the quality C1, about 25μ diameter, was decided upon.

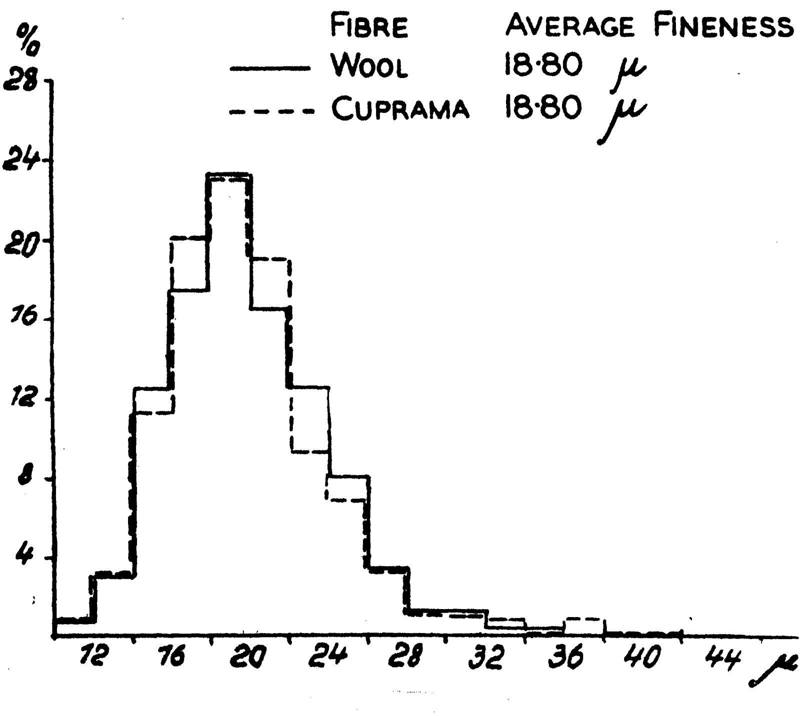
The Zeiss Lanameter.

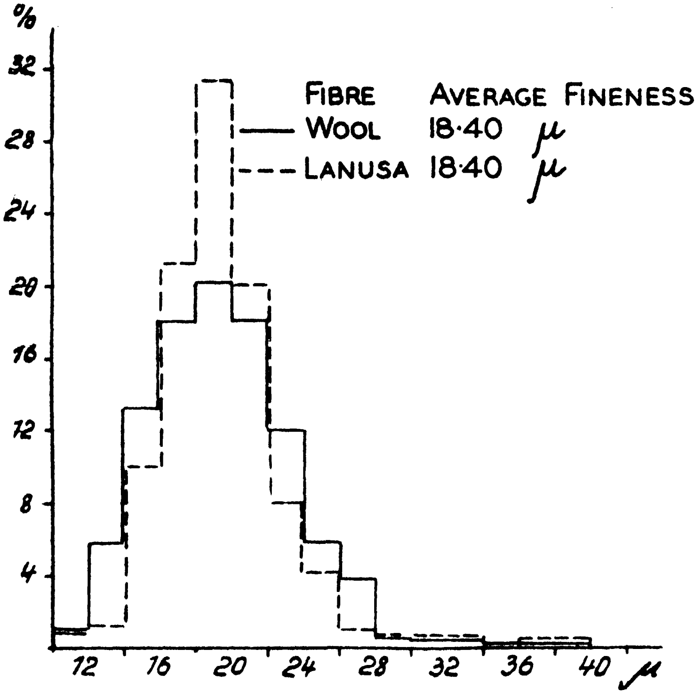
The instrument consists mainly of an inverted microscope. This projects an image of the fibres under inspection, accurately magnified 500 times, on to a ground glass screen. There the fibres are measured by a half-millimeter scale which is incorporated in the screen. The illumination of the slide is contrived by means of a lighting device powerful enough to make measurement easy in an undarkened room.

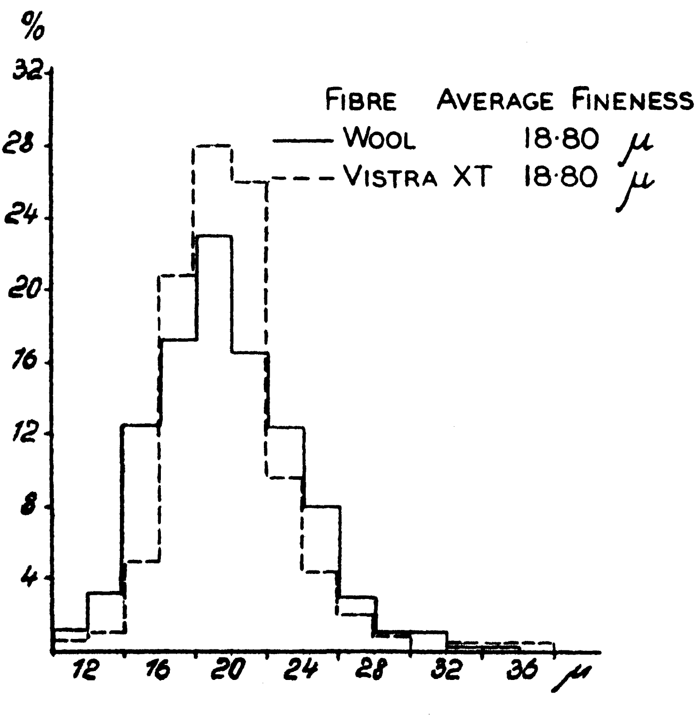
Details are given in the illustration. A desk-shaped box carries on its upper horizontal surface a lamp house (1) with a centring socket for the bulb. A

*** If particularly accurate measurement is required, it is recommended that the results be treated statistically.**


%
28
24
20
16
12
8
4
FIBRE
AVERAGE FINENESS
WOOL
20·60 μ
SCHWARZA
20·60 μ
12
16
20
24
28
32
36
40
44
48
52


%
28
24
20
16
12
8
4
FIBRE
AVERAGE FINENESS
WOOL
18·80 μ
CUPRAMA
18·80 μ
12
16
20
24
28
32
36
40
44
μ


%
32
28
24
20
16
12
8
4
FIBRE AVERAGE FINENESS
WOOL 18·40 μ
LANUSA 18·40 μ
12
16
20
24
28
32
36
40
μ


%
32
28
24
20
16
12
8
4
FIBRE AVERAGE FINENESS
WOOL 18·80 μ
VISTRA XT 18·80 μ
12
16
20
24
28
32
36
μ

low voltage lamp of 6 volts 1·2 amps. is provided, which can be connected to alternating current mains through a transformer, or to direct current mains through a resistance. The same bracket carries the lighting system (2). This consists essentially of a two-part collector lens and a condenser. The slide is moved by the carrier (3) on to the table (7) attached to the roof of the box.

Below the table is the objective (8) an achromatic lens specially corrected for the purpose. The tube (9) hangs perpendicularly inside the house. At its lower end is the eyepiece (10). This requires adjustment only according to the thickness of the slide. The micrometer screw is turned by the milled head (6). It is so arranged as to be convenient for use while working. For adjusting the object there are two milled heads (4), also conveniently placed, by means of which the slide can be moved in two directions.

The image thrown by objective and eyepiece is reflected by a surface-silvered mirror (11) on to the ground glass screen (5) where it is measured, as described above, by the built-in scale. The distance from microscope to screen is such that, using the objective recommended, the material is magnified directly in the ratio 500 : 1.

In order to facilitate calibration which is of importance in arbitration questions, the mirror is provided with an adjustment easily accessible from outside.

Application of the Zeiss Lanameter to the Measurement of Rayon Staple Fibre.

It is customary to measure the fineness of rayon staple fibre in denier. For the determination of this a definite length is weighed and the denier calculated therefrom. Only the mean fineness, however, can be obtained in this way, whereas in recovery and re-manufacture of the material, as in the case of wool, a measure of the distribution of fineness is necessary. This can be quickly obtained with the Zeiss Lanameter from rayon staple fibre with a more or less circular cross-section, in particular Lanusa, Schwarza, Vistra XT, Lanital, and all fibres produced on the cuprammonium system. Curiously enough it was found that the distribution approximates to that of a normal A quality, as the accompanying diagrams will show.

If fineness distributions similar to crossbred are desired, however, it would appear necessary to blend together various deniers.

SEVENTH INTERNATIONAL MANAGEMENT CONGRESS

Following upon the very successful Congress held in London in July, 1935, in which the Textile Institute actively participated, the Seventh International Management Congress will be held in Washington, D.C., from September 19th to 23rd, 1938, under the auspices of the International Committee of Scientific Management, of which Viscount Leverhulme is President. Members of the Textile Institute are doubtless aware that Lord Leverhulme is also Chairman of the recently formed British Management Council, of which the Institute is a Constituent Member.

The organisation of British participation in the Seventh International Management Congress is in the hands of the Congress Committee of the British Management Council on which the Institute is represented by Mr. Nasmith. Under the supervision of this body some fifteen to twenty papers are in the course of preparation for the Congress.

The Congress is receiving support from all responsible management bodies in the United States, such organisations as the American Management Association and the American Society of Mechanical Engineers, taking an extremely active part in the arrangements. The American Congress Council is under the Chairmanship of Mr. Willis H. Booth, Honorary President of the International Chamber of Commerce and Chairman of the Board of the Edison General Electric Appliance Co. Inc.

Not only will the Seventh International Management Congress provide an opportunity for students of management to meet and discuss mutual problems with those men and women who are developing the science in the United States, but it will also provide the most favourable opportunity, both in terms of convenience and expense, which is likely to occur for many years, of seeing the outstanding examples of the application of American management methods to business undertakings and of talking with the people, who are actually working under the conditions created by these methods.

Two themes have been selected for discussion at the Congress: " Recent Development in Management " and the " Social and Economic Aspects of Management." The first of these themes upon which all papers for the Congress are being written permits of the treatment of any aspect of management provided that the problem dealt with represents a recent development, which for the purposes of the Congress is to be taken to mean a development which has either manifested itself or has made definite progress since the London Congress. This theme will be discussed at a series of technical sessions in each of the six following sections of the Congress—Administration, Production, Distribution, Personnel, Agriculture and the Home. The second theme for the Congress will provide management with an opportunity to appraise the social and economic results of its work and discern its future course in rapidly changing conditions and the new concepts of its responsibility which are developing to-day.

The Congress will offer to its members unparalleled opportunities to visit those works and offices which afford the best practical examples of American management methods.

Arduous treks through factories are not contemplated but rather a brief visit to a specific department or section of the organisation in question, which will be selected as representing an outstanding example of some particular aspect of good management practice. Several alternative visits will be available each day.

The Congress will afford a unique opportunity to its members for meeting those in other countries who are working on the same problems as themselves. Special arrangements will be made to facilitate the making of any particular contacts in the United States which a member may desire, thus enabling him to make the most economical use of his time.

The cost of attending the Congress promises to be surprisingly low, and it will be of interest to those with whom expense is a consideration to know that

the cost of the entire trip, including a week at the Congress and a fortnight's works visits, living throughout at first-class hotels in America, can be less than £100.

All enquiries should be addressed to: —

The Secretary
The British Management Council
Room 68, Armour House
St. Martins-le-Grand, London, E.C.1.
Telephone No. Central 7474, Extension 592.

Reviews

The Biochemistry of Cellulose, The Polyuronides, Lignin, etc. By A. G. Norman, Ph.D., D.Sc. (Published by Humphrey Milford, Oxford University Press, Oxford, pp. 232. Price 15/- net.)

Within recent years remarkable advances have been made in the elucidation of the molecular structure of cellulose, and although the position with regard to the other substances that accompany cellulose in the plant cell-wall is not so satisfactory, important progress has been made here also. The literature dealing with these substances is so voluminous and the mass of data so difficult to digest by those not familiar with the subject that an authoritative survey of the present state of knowledge is sorely needed. This need is admirably filled by the present book.

The eight chapters deal with the following subjects: (1) cellulose (including the hexosans and pentosans intimately associated with the " true " cellulose in the plant), (2) polyuronide hemicelluloses, (3) pentosans, hexosans and hexopentosans (" polyose " hemicelluloses), (4) pectin, (5) gums, mucilages and gel-forming substances, (6) lignin, (7) metabolism of plant cell-wall constituents, (8) microbial polysaccharides. In addition, there is a useful appendix dealing with the characterization and structure of the uronic acids, and with the determinations of uronic acids and pentoses which play so important a part in the investigation of plant products.

The book is not merely a summary of the literature. Having done research in most parts of the field reviewed, the author is able to subject the results and views of other investigators to critical examination. This critical treatment adds greatly to the value of the survey.

The section dealing with the constitution of cellulose is rather sketchy and not always accurate. It came as a shock to the reviewer to find (p. 5) Staudinger and Hess grouped together as exponents of the theory that cellulose consists of small molecules held together by residual valency forces. One would have thought that in his 160 papers " Uber hochpolymere Verbindungen " Staudinger had established his position as the most doughty champion of the macro-molecular structure of polymers. The chapter on pectin is one of the best in the book, but it is a pity that no reference is made to the recent work of Schneider, which provides strong support for the view that the pectin molecule is a long chain of galacturonic acid residues.

The book is for the most part clearly written, but there are occasional lapses into slipshod methods of expression. For example, a monodisperse solution is defined as one that contains " homogeneous particles " (p. 9), and it is stated that certain solutions " possess a limited solubility for cellulose " (p. 16). The sentence " Owing to their heterogeneous nature, microchemical tests for the encrusting polyuronides are not very satisfactory " (p. 68) would have delighted the authors of " The King's English."

As the author explains in the preface, the substances dealt with are considered as plant constituents rather than as raw materials of industry. Consequently the book contains little of direct practical utility to the cotton technologist, although it should be more useful to textile chemists concerned with the bast fibres. It should, however, be read with profit by all who are interested in cellulose chemistry.

The printing and binding are up to the usual high standard of the publishers. G.F.D.

Wetting and Detergency (Scientific and Technical Aspects). (Published by A. Harvey, London. (207 pp.) 15/- net.)

This book contains the twenty papers, and the discussions to which they gave rise, that made up the Symposium organised by the British Section of the International Society of Leather Trades' Chemists in February of this year. Together with the companion volume on "Emulsions," which contained the papers and discussions of a previous Symposium, the new volume provides a concise summary of most of the recent theoretical advances bearing on these important subjects, with examples of their successful application to the elucidation of problems in many industries.

From the standpoint of the textile industries, "Emulsions" might be said to have been concerned with the physical chemistry of the formation and stabilisation of the colloidal solutions which result when detergent solutions are used to remove "dirt," oils and greases from the surface of fabrics. "Wetting and detergency," on the other hand, is concerned mainly with the physical chemistry of the processes which precede the formation of such emulsions: the preliminary wetting of the "dirt," grease, and surfaces to be cleaned, the loosening of the forces of attachment between the "dirt" and grease and the surface, the relation between the chemical constitution and the physico-chemical properties of detergents that assist these important processes, and also how these processes are hindered or assisted by the physical, chemical, and mechanical properties of the surfaces and fabrics.

As stated in a foreword by Dr. Clayton, one of the outstanding characteristics of the present collection of papers is that they show an increasing tendency on the part of chemists and physicists to place wetting and detergency on a quantitative basis: many of the papers deal with the accurate measurement of physical constants—contact angles, adhesion tensions, heats of wetting—with which wetting and detergent action are related.

During recent years a large gap had arisen between the knowledge gained in academic and technical laboratories and the information available to the chemist in industry. This volume serves to bridge this gap and is worthy of careful study by all those interested in the scouring, finishing and dyeing of textiles. H.P.

Davison's Textile Blue Book, 1937. Published by the Davison Publishing Co., 50, Union Square, New York City. Price 5.00 dollars.

Davison's Textile Blue Book for 1937 is an outstanding product. Much care and thought have obviously been spent in its compilation. A fine feature, greatly facilitating easy reference, is the thumb-indexing, a process which could advantageously be much more widely employed in reference books and directories. Printer, book-binder and map-maker can all be congratulated on this work. T.

Additions to the Library

Ramie. A Critical Survey of Facts concerning the Fiber-Bearing Plant "Urtica Nivea," by G. L. Carter, Ph.D., and P. M. Horton, Ph.D., Louisiana State University Studies No. 26. Louisiana State University Press, Baton Rouge, La., 1936.

The Brown-Firth Research Laboratories. Thos. Firth and John Brown Ltd., Atlas and Norfolk Works, Sheffield. A descriptive brochure.

Seventeenth Annual Report of the Industrial Health Research Board. To 30th June, 1937. London H.M. Stationery Office. Price 9d. net.

A Guide to Indian Cottons. Joint Publication of the East India Cotton Association Ltd. and the Indian Central Cotton Committee. Published by the Indian Central Cotton Committee, Bombay. Price 6 annas.

Lancashire Indian Cotton Committee. 3rd Annual Report, 1936.

Institution of Mechanical Engineers. Papers presented for general discussion on Lubrication and Lubricants, 13th, 14th, and 15th, October, 1937.

Group I—Journal and Thrust Bearings. Price 2s. 6d. net.
Group II—Engine Lubrication. Price 2s. 6d. net.
Group III—Industrial Applications. Price 2s. 6d. net.
Group IV—Properties and Testing. Price 2s. 6d. net.

Published by the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1.

Razas Ovinas. (*Breeds of Sheep.*) By Professor Pablo Link. Published by S. A. Casa Jacobo Peuser Lda., Buenos Aires, July 31st, 1937. (No price stated.)

Apart from the preface the whole book is devoted chapter by chapter to a study of fifteen leading varieties of sheep suitable for breeding in the Argentine Republic. These are the Argentine Merino, the Australian Merino, the Polwarth, the Corriedale, the Southdown, the Shropshire, the Hampshire Down, the Oxford Down, the Ryeland, the Dorset Horn, the Leicester, the Border Leicester, the Romney Marsh, the Lincoln and the Karakul. It is interesting to note that of these breeds the Lincoln accounts for 62 per cent. and the Romney Marsh for 14 per cent. of the entries in the Argentine Flock Book between 1898 and 1936.

Professor Link subdivides each chapter into sections in which he deals with the origin, geographical distribution, points, characteristics, advantages and disadvantages of each breed.

In the chapter devoted to the Polwarth, Professor Link says that there still exist individual defects peculiar to each type due to atavism and reversion, and generic defects common to all types in spite of the constant pains taken in selection and improvement. Even if a perfect sheep were to exist, continues Professor Link, it is highly improbable that he would transmit all his good points to his progeny. The breeder has constantly to be on the look out and to reject animals showing grave individual or generic faults, for the work of many years of unremitting toil may be undone by one season of imperfect care.

In the preface, Professor Link defines the aim of a wool grower as the improvement and maintenance of wool production at the highest level of output compatible with quality.

The work is intended to be descriptive and analytical, enabling the reader to form an idea of the economic possibilities of each type. The author hopes to write further books dealing with the " pure science " and the " applied science " of wool growing, that is to say, with other phases of the industry such as the cost of nutrition and its effect on yield, marketing, etc.

The subject matter is excellently presented and illustrated by numerous photographs, maps and diagrams. D.G.P.

Correspondence

" MODERN DRAFTING IN COTTON SPINNING "

BY J. NOGUERA.

To the Editor, Sir,

In reply to the comments of the Author, published in the July issue of the *Journal of the Institute*, I am in agreement with him as regards the effects of doubling for the feeds of preparation machines. I intended only to question his method of expressing himself on regularity due to doubling, which in my opinion is confusing. The term " irregularity " as printed in the June issue of the *Journal* was a mis-quotation. I fully appreciate the effects of doubling by the tendency to even the feed proportionally, and also the defects of further calls on drafting mechanism. I submit that the general effects on the processed material are best expressed either as beneficial or detrimental, if the person seeking information on this problem is to be assisted.

On re-examining his reference to Fig. 2 regarding doubling, I find that he quotes the basis for the example given as " two six-yard lengths of card sliver " and agree with him that the variation percentages as published in the book are correct. A diagram showing percentage variations by varying thicknesses on a sliver of basic thickness, rather than two sets of parallel lines with six sections variably marked, would however be more helpful to readers when considering the useful information given. H.B.

NOVEMBER 1937 P377

THE JOURNAL OF THE
TEXTILE INSTITUTE

Vol. XXVIII NOVEMBER 1937 No. 11

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

Council Meeting for November

The monthly meeting was very well attended and while the time available was short—the presentation of the Institute Medal being made later in the afternoon—some important matters were discussed. At the outset members stood in silence as a mark of respect to Mr. Frank Wright and Mr. James Crawford to whose passing reference is made below.

The usual routine business having been disposed of, reference was made to the next Annual Conference. This is to be held in Scotland and one event in the programme will be a visit to the Empire Exhibition at Glasgow. This will occupy a whole day and lunch and probably tea will be taken in the Exhibition grounds. The venue chosen, subject to suitable accommodation being available, is Peebles and it is anticipated that a very attractive programme of events will be arranged. The Conference Committee has already met and is working in close association with the Scottish Section Committee to provide an interesting Conference.

The general subject for discussion is " Education in relation to the Textile Industries," and this will be dealt with on the plan adopted at Southport this year. Two speakers will open the discussion each session and other contributions, printed in advance, will be made. The Publications Committee will be glad to receive offers of written contributions as soon as possible and it is hoped in this way to build up a very valuable series of papers on this important subject.

Obituary: Mr. Frank Wright and Mr. James G. Crawford

The Institute has during the past few months been singularly unfortunate in losing several of its older and most staunch members. Of recent years, no one has taken more definite interest in our work than Mr. Frank Wright. On his retirement Mr. Wright appeared to have found in the Textile Institute something to which he could put his hand with enthusiasm and which would occupy, at least in part, some of his leisure. He served on several Committees and then became Chairman of Council. He interested himself in every detail and in an ex-officio capacity attended Section and Committee meetings whenever possible. Later he became a Vice-President and he was also awarded the Institute Medal. Up to a very late stage in his illness he evinced a real interest in Institute affairs. At his funeral on Saturday, 20th November, the Institute was represented by Mr. Frank Nasmith, Vice-President and Hon. Secretary, Mr. W. Kershaw, Vice-President, and Mr. H. L. Robinson, General Secretary.

Mr. James G. Crawford, Managing Director of the York Street Flax Spinning Co., Belfast, was a member of the Institute from its early days. Whilst never taking a very active part in its work, Mr. Crawford was always interested and responded readily to any requests made for specific help. The Irish Section will miss his very real support.

Presentation of Medal to Dr. F. W. Eurich

As announced in the October issue of this *Journal,* Council recently awarded the Institute Medal to Dr. F. W. Eurich, of Bradford, for his research work on Anthrax. The actual presentation of the medal was made on Wednesday, 17th November, after the regular meeting of Council. Mr. John Crompton, President, presided and Mr. George Garnett, Past-President, introduced Dr. Eurich to the President who then handed the medal to the recipient with appropriate remarks. Dr. Eurich giving thanks to the President and Council for the award referred to the work of other medical men in the field of Anthrax research and also to the work of the members of the Anthrax Investigation Board. The meeting was attended by representatives of Wool Trade organisations and by members of the Institute Council and by the press.

Rubber Technology

The Council of the Institution of the Rubber Industry announces that the Rubber Division of the American Chemical Society is willing to support the Annual Conference, to be held in London from 23rd to 25th May, 1938. In Part I, papers will be discussed dealing with methods of improving and evaluating the durability or rubber. In Part II the papers will deal with rubber generally. Particulars may be obtained from the Secretary, Institution of the Rubber Industry, 12, Whitehall, S.W.1.

Employment Register

The following announcements are taken from entries in our Register of members whose services are on offer. Employers may obtain full particulars on application:—

No. 140—Young man, 29 years of age, desires position as Manager in Woollen Mill, able to take full control. At present employed by firm making all types of Fancy Woollen cloths—worsted warp/woollen weft, cotton warp/woollen weft, suitings, overcoatings, Ladies' dress and coating, etc. Conversant with designing and all processes from raw material to finished cloth and with customers' requirements. Holder of City and Guilds Certs. and Diplomas. Excellent references. Experience in handling workpeople.

No. 170—Young man, 26 years of age, requires responsible position in executive capacity with large Textile house. B.Sc.Tech. Two years' experience of Textile Testing and 5 years' as Shift Manager. Willing to go abroad.

No. 171—A.T.I., 32 years of age, desires position as Cotton Spinning Mill Manager or progressive position in Textiles. Full Tech. Cert. in Cotton Spinning. Nat. Cert. in Electrical Engineering. 5 years' experience in Electrical and Mechanical Engineering and 11 years' in all depts. of Cotton Spinning Mill.

No. 172—A.T.I. requires Managerial or Executive position. Full Tech. Cert. in Manufacture of Hosiery and Knitted Goods. 4 years' apprenticeship with Knitting firm, 1 year Nottingham University. Knowledge of costing, labour control and modern knitting machinery.

No. 173—Young man, A.T.I., age 30, married, desires position as Chemist-dyer, assistant manager or responsible position in dyeworks. 12 years' practical experience rayon and associated fibres, knitted fabrics, yarn and hosiery, also expert knowledge of Azoic and Vat colours. City and Guilds Full Tech. Cert. in Dyeing Silk and Rayon, Nottingham University College Diploma Textiles, present Examiner.

No. 174—Desires position of responsibility, preferably in India. Practical experience in erection of machines. 1st Class Diploma of City and Guilds' Institute in Plain Weaving (Final).

No. 175—Applicant desires position as Head Carder at a large Mill or inside Manager. Full Technological Certificate, 2nd Prize for Bolton Master Spinners on Cardroom processes. A.T.I. 5 years' experience as Head Carder.

Institute Membership

At the October meeting of the Council, the following were elected to Membership of the Institute:—

Ordinary

D. C. Allan, c/o John Shields & Co. (Perth) Ltd., Wallace Works, Perth (Secretary).
C. K. Altham, 4, Ribble Avenue, Grindleton, nr. Clitheroe (Mill Manager).
M. H. Brierley, c/o Universal Winding Co., 20, Dixon Street, St. Enoch's Square, Glasgow, C.1 (Scottish Representative).
E. W. Chan, Y.M.C.A., Forster Square, Bradford (Student).
J. Chirnside, 9, Queen's Road, Cheadle Hulme, Cheshire (Lecturer in Textiles, Manchester College of Technology).
C. C. Choudhury, c/o The Banga Sri Cotton Mills Ltd., Sodepore, 24, Parganas, Bengal, India (Mill Manager).
A. Collins, c/o Collins Brothers Pty. Ltd., Geelong, Victoria, Australia (Woollen Manufacturer).
R. Cuthill, M.Sc., Ph.D., 19, Bolton Villas, Bradford (Lecturer in Physical Chemistry, Bradford Technical College.
Sir John H. Grey, Livingstone Mill, Burnley (Cotton Manufacturer).
Wm. A. Guest, Rua Azevdo Coutinho, Avenida da Boa Vista, Porto, Portugal (Bleachworks Manager).
J. E. Haygarth, Seeburn, Baildon, Yorks. (Director, Preston Street Combing Co. Ltd., and Smith Adams Separator Co. Ltd.).
H. Hilton, A.M.C.T., 15, Canterbury Street, Chorley, Lancs. (Chemist Dyer, Dacca Mills Co., Heapey).
C. L. Hird, 39, Boulton Lane, Alvaston, Derby (Chemist, British Celanese Ltd., Spondon).
G. Keighley, 119, Westfield Road, Manningham, Bradford, Yorks. (Dyers' Chemist, Lister & Co. Ltd., Manningham Mills, Bradford).
H. King, 70, The Hollins, Sowerby Bridge, Yorks. (Anglo-Continental Drawing and Spinning Foreman).
N. J. Legg, "Rosslyn," Nether Close, Duffield, nr. Derby (Textile Assistant, Research Dept., L.M.S. Railway Co., Derby).
J. Longworth, 11, Wythburn Avenue, Smithills, Bolton (Technological Assistant, Haslam Spinning Co. Ltd., Bolton).
R. C. Mathur, Municipal College of Technology, Manchester (Student).
F. McKay, B.Sc.Tech., 45, Beechfield Road, Smithills, Bolton (Weaving Lecturer, Bolton Municipal Technical College).
A. Robinson, Arlen, Leyland Lane, Leyland, Lancs. (Works Chemist, John Stanning & Son, Ltd., Leyland).
A. Smith, 13, Bedford Avenue, Mansfield, Notts. (Cost and mill control clerk, Harwood Cash & Co. Ltd., Mansfield).
E. H. Stansbie, M.A. (Oxon.), Nelsons Silk Ltd., Caton Road, Lancaster (Silk Works Manager).
N. Williams, 151, Belmont Road, Bolton (Under Carder).

Junior

H. M. Appleyard, 21, Deneside Terrace, Bankfoot, Bradford (Woolsorter).
S. P. Chowdhury, University College, Shakespeare Street, Nottingham (Student).
G. Coppieters, c/o Mrs. Matthews, 4 Albany Terrace, Dundee (Student).
F. H. Dixon, "Burtrey," Laurence Road, Halifax (Woollen Manufacturer's Assistant).
N. N. Fearn, 1, Collin Street, Beeston, Nottingham (Works Chemist).
G. H. Green, The Grove, 75, Cleckheaton Road, Odsal, Bradford (Manufacturing and selling piece goods).

C. Howden, Wool Industries Research Association, Torridon, Headingley, Leeds, 6 (Testing of fibres, etc., Applied Physics Dept.).

G. Hughes, c/o Donaghy's Rope and Twine Ltd., Auckland, New Zealand (Mill Manager).

J. E. Priestley, Grove Mills, Halifax (Assistant Manager, Priestley Bros., Halifax).

N. Schofield, 86, Fagley Road, Bradford, Yorks. (Clerk and Colour Matcher to worsted spinners).

S. A. E. Seood, c/o Misr Spinning & Weaving Co., Mehalla el Kobra, Egypt.

At the November meeting of the Council, the following were elected to Membership of the Institute:—

Ordinary

C. Eugene Coke, M.Sc.(Man.), A.I.C., Dept. of Textile Research, The University, Leeds (Research Scholar).

J. G. Coutts, 103, Davies Road, West Bridgford, Nottingham (Departmental Manager).

J. A. Simoes de Almeida, Rua Castilho 15, 1°, Lisbon, Portugal (President of the Regulating Committee for Trade in Raw Cotton).

E. Jorgensen, 25, Ravenhill Park Gardens, Belfast (Foreman and Hosiery Machinist).

Dennis Moss, Albert Mills, Morley, nr. Leeds (Cloth Finisher).

D. W. C. Moulton, Boyne Hill Laundry, Maidenhead (Laundry Manager).

H. R. Mushlian, 62, Barton Arcade, Manchester, 3 (Chartered Patent Agent, William Gadd & Sons).

G. H. A. Sington, M.I.Mech.E., c/o Messrs. Platt Bros. & Co. Ltd., Hartford Works, Oldham (Director).

Lancashire Section

HIGH NICKEL ALLOYS FOR TEXTILE WET PROCESSING PLANT

N. C. MARPLES, M.Sc. (Messrs. Henry Wiggin & Co. Ltd.)

Abstract of Lecture given to the Lancashire Section of the Textile Institute in Manchester, on September 22nd, 1937.

While the art of dyeing and bleaching dates back over several centuries and mechanical processes for carrying out these operations have been in use for over a century, it is only in comparatively recent years that the textile worker has been able to obtain metallic materials other than steel, cast iron and copper for the construction of his equipment. In the present paper the properties of some alloys containing high percentages of nickel are discussed, particular stress being laid upon their suitability for use in the construction of plant for textile wet processing. Three materials will be considered:—

(*a*) Monel, an alloy containing 2/3rds nickel and 1/3rd copper.

(*b*) Inconel, an alloy containing 80 per cent. nickel, 12/14 per cent. chromium and approximately 6 per cent. iron.

(*c*) Malleable nickel.

Pure nickel will not be discussed as such but rather as a material termed nickel clad steel, which is so utilised in construction that the equipment presents only the pure nickel surface to the processing solutions.

All three materials have high resistance to corrosion by chemical action and this property is required, as will be agreed, from considerations additional to the mere prolongation of the life of the plant. Poorly resistant materials may, for instance, combine with some of the dyestuffs employed, thus putting the product offshade in an objectionable fashion. Similarly, poorly resistant materials may give rise to stains and marks on the goods undergoing treatment. They may have a catalytic effect on the chemical substances used in the process. Also under corrosive action they may become roughened and damage the goods. Before turning to a closer consideration of the three nickel containing materials mentioned, the limitations of the materials used as alternatives will be discussed briefly.

Steel has been little used in the textile industry except for constructional purposes. It may be used for such vessels as bleaching kiers, where the design is such that the fabrics do not come into intimate contact with the material. The readiness with which steel rusts and the possibility of the fabrics staining, naturally limit its usefulness quite apart from the fact that in the dyeing process a very large number of dyestuffs are affected by iron. Cast iron has been quite widely used for the construction of jiggers and can be successfully employed for certain ranges of dyestuffs. Copper has been quite widely employed but in certain circumstances it may produce unpleasant staining and has also a marked effect on some dyestuffs.

So limited has been the application of these three metals that it has been necessary in the past to supplement them with wood, slate, porcelain and ebonite. Each of these substances, while it may be satisfactorily resistant to corrosion over a wide range of processing solutions, is usually inferior to metals in toughness and resistance to temperature changes. Wood has been until recently, probably the most commonly used material for dye vat construction, and is in many ways admirable, except for the fact that its porous nature allows it to absorb the dyestuffs and in consequence a change over from one shade to another can be effected only if the vat is boiled out for a considerable period before introducing the new colour.

There is therefore a wide scope for materials which:—

(1) possess good general chemical and mechanical resistance,

(2) are readily worked and thus easily brought into the required shape,
(3) possess and retain a smooth non-porous surface.

Monel, which possesses these properties, therefore found ready acceptance in the textile industry when it was introduced into this country shortly after the war. Its excellence for many processes is widely recognised and it is only in the dyeing of wool fabrics, owing to its susceptibility to sulphur attack, that it is of limited utility. For this purpose, Inconel, which has similar strength and the ready workability characteristic of Monel, seems likely to meet all requirements in the way of immunity from staining by the acid liquors used in the wool dyeing processes.

The characteristics of the nickel alloys under consideration will now be reviewed.

Table I. Physical Constants of Monel.

Density	8·80
lbs. per cu. in.	0·318
Melting point	1350° C.—2460° F.
Specific heat (20°-400° C.)	0·127
Coefficient of expansion (25°-100° C.)	0·000014
(25°-300° C.)	0·000015
Electrical Resistivity (at 0° C.)—microhms/cm³	42·5
Young's Modulus, pounds per sq. in.	25,000,000 to 26,000,000
Rigidity Modulus, pounds per sq. in.	8,000,000 to 9,000,000
Magnetic transformation	95° C.—203° F.

Mechanical Properties of Monel.

NOTE.—Monel metal cannot be hardened by thermal treatment. Its mechanical properties can, however, be considerably enhanced by cold working, and for certain purposes it is definitely advantageous to employ it in a hard rolled or hard drawn condition. The mechanical properties of the hard rolled or soft annealed qualities in various forms are shown here.

Type	Condition	Ultimate Strength Tons/sq.in.	Yield Point Tons/sq.in.	Elongation On $4\sqrt{area}$	Hardness
Hot Rolled Rounds, Squares, Rectangles or Hexagons : Forgings	Normal	34-38	15-18	35%	120-140 Brinell
Cold Drawn Rounds or Hexagons : Cold Rolled Squares or Rectangles	Hard (A)	40-45	35-40	18/20%	190-210 Brinell
	Annealed (A)	30-35	14-17	35%	110-120 Brinell
(B) Full Finish Sheet	Normal	30-33	14-16	30%	18-20 Scleroscope
Cold Rolled Sheet or Strip	Hard (A)	45-50	40-45	15%	38-42 Scleroscope
	Annealed (A)	29-30	14-16	30%	16-18 Scleroscope
Cold Drawn Wire	Hard (A) for Springs	55-60	50-55	5/10%	—
	Annealed (A)	29-33	14-16	35%	—
Castings : Normal Quality	As Cast	19-23	12-15	12%	110-130 Brinell
Special Silicon Quality	Thermally Hardened	38-40	22-25	10/15%	190-210 Brinell

(A) Where desired, cold rolled or cold drawn material can be produced to hardnesses intermediate between full hard and soft annealed.

(B) This grade of sheet was previously designated hot rolled but is now finished by cold rolling to give a bright surface. The sheets are flat and are recommended for moderate drawing and all bending operations.

Monel

As already noted this alloy contains approximately 2/3rds nickel and 1/3rd copper and its physical and mechanical characteristics will be seen in Table I. It will be noted that in its softest condition it has a tensile strength of over 30 tons/sq. in. which is about 15 per cent. stronger than ordinary mild steel. Monel is silver white in colour and has a density similar to that of copper. Its coefficient of expansion is moderate so that undue distortion during welding does not tend to render this process difficult. Among all corrosion resisting materials Monel is indeed outstanding in the ease with which it can be fabricated. It can be fairly readily machined, drilled or screwed provided a slight adjustment to the tool angles is made. It can be cast into fairly intricate shapes which are resistant to corrosion and which do not depend upon being highly polished for immunity from rust. It can be pressed and spun and its annealing temperature of 800-900° is within the reach of the furnaces and equipment usually available. Naturally in all equipment, joints are of primary importance. As it is the practice to use Monel for the lining of cast iron or wood vats and to make such linings of sheet from 1/64″ to 1/32″ thick, it is advantageous that Monel can be joined by lock seaming and soft soldering. This method has been employed with success in some thousands of dye vat linings at present in use in this country. Provided care is used in forming the lock seam and a good quality soft solder is sweated into the joint from outside, the amount of solder exposed to the dye liquid is practically negligible, while the capacity of Monel for bonding with solder is so good that joints made in that way will last even under severe conditions for many years.

Where new machines are being built for which it is desirable to use heavier gauge sheet, i.e. say about 1/16″ thick, very good oxy-acetylene welded joints can be made and it is of importance that such joints possess corrosion resistance equivalent to that of the parent metal, and that descaling in the vicinity of these is not a necessary feature to obtaining full corrosion resistance. Moreover, no heat treatment of the welded portion is necessary to avoid the weld decay troubles common with some of the materials of the Austenitic stainless steel type.

Resistance to Corrosion in Dyebaths

Before considering further textile applications of Monel, it may be profitable to discuss the suitability of the alloy from the chemical point of view for the different classes of dyestuffs. Fortunately, besides practical experience in the dyehouse, there is also available the extensive series of tests made by the Clayton Aniline Company Limited upon the modifying influence of most of the possible constructional materials upon the shades of different classes of dyestuff.

Direct Cotton Colours. These dyes, generally applied from dilute solutions with additions of neutral salts (Glauber's salt, common salt) slightly alkaline salts (sodium phosphate, soaps or other wetting agents), are unaffected by Monel. Certain dyestuffs of this class may be after-treated by diazotisation and development. The process of diazotisation and development is dealt with in the section on developed colours.

Acid Colours. According to the results of the Clayton Aniline Company Limited, the behaviour of Monel with these dyes is good, being, however a little less satisfactory than pure nickel for a small proportion of the total number of dyes of this class that were examined. As a rule, the baths must be distinctly acid and it is advisable therefore to empty them at the end of each day.

Acid Chrome Colours. Where dyeing requires the use of an acid solution of bichromate, as in most of the methods of applying the chrome colours, the resistance of any metallic material is put to a much more severe test by the conjunction of acid and oxidising agent. It must, therefore, be admitted that these

colours are more liable to attack by Monel than by certain of the corrosion resisting ferrous alloys or by Inconel. Reference to this will be made later. The results of the Clayton Aniline Company Limited who used appropriate after-chroming treatment, show that many of the browns and blues are rendered redder in shade, although in compound shades it is possible to allow for this in varying the proportion of shading dyes.

Developed Colours and Azoic Colours. Here, again, one part of the dyeing process requires the use of somewhat strongly acid solutions of the oxidising agent. The nitrous acid is used, it is true, in the cold but since it is the nitrous acid in excess of that required for the diazotising reaction which is active in corroding metals, careful control can do much to avoid any corrosion of the metal. The form of dyeing in this process has also a marked effect, since the amount of chemical introduced into the diazotising bath varies with the weight of goods to be dyed. Consequently, therefore, in continuous processes such as jig dyeing, the effect on the metal is likely to be greater than in say, reel type piece goods dyeing machines where the weight of goods handled is in a much smaller ratio to the volume of dye liquor.

An actual test carried out in the Monel machine used in the dyeing of a fabric with developed colours, where care was exercised in controlling the conditions, showed that the amount of attack was only 0·0023″ per year; practically a negligible amount and one which was borne out by the successful years of operation by that particular machine working mainly on developed colours. Nevertheless, where developed colour work is to be extensive, then the use of Inconel can usefully be considered.

In general Monel gives satisfactory results with basic colours when employing usually accepted methods of mordanting and dyeing.

Vat Colours. One of the principal features of Monel is its excellent resistance to the action of alkaline solutions and for vat colours applied in the orthodox way very good results are obtained. Cleanliness is of the utmost importance in vat dyeing and the ability to wash vessels perfectly clean between lots is very advantageous. Monel withstands the action of the alkaline or weakly acid oxidising agents required for oxidising the dyestuff.

Sulphur Colours. Since these colours are dyed from an alkaline bath of sodium sulphide, copper is attacked and the shade of materials dyed in copper vessels is severely modified. Iron is often used for dyeing sulphur colours and because of the generally good resistance of iron to alkaline liquors and also to the formation of a resistant layer of sulphide of iron on the container, the results are generally satisfactory. However, if the machines are used for other dyeing processes requiring acid or oxidising reagents this layer is removed and the net effect is one of corrosion. Sodium sulphide liquors have a bad effect on wood, if used continuously. With most sulphur dyes, very satisfactory results are obtained with Monel, and it is then not necessary to reserve certain machines for the use of sulphur colours only.

Dyehouse Equipment

Monel is being employed successfully in the dyeing of cotton, pure silk and artificial silk hosiery. It exhibits satisfactory resistance in the scouring, degumming and dyeing of hosiery. In some rotary machines the containers are lined and the cages are made from this material. In other rotaries an all Monel construction is employed.

In paddle machines Monel enables smooth surfaced well-balanced and durable paddles which do not warp or splinter to be built.

Winch dyeing machines are used frequently for fabrics too delicate to be dyed in jiggers and they require therefore that the construction of the machine shall avoid abrasive action. Monel by virtue of its smooth surface fulfils this condition satisfactorily. The becks of iron and wooden jiggers can be readily

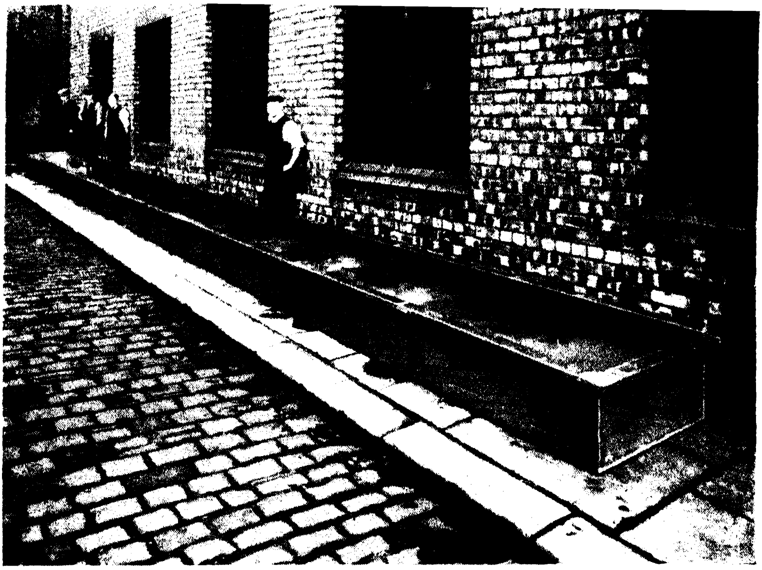


Fig. 1.

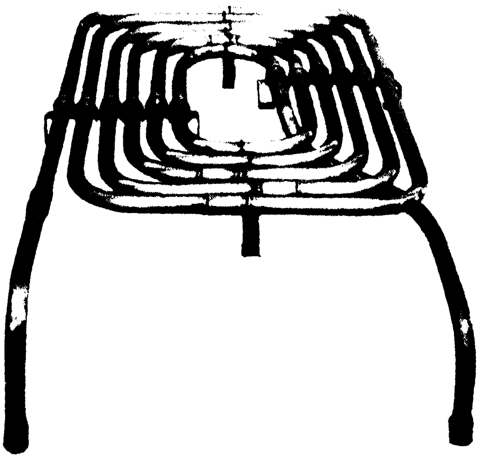


Fig. 2.

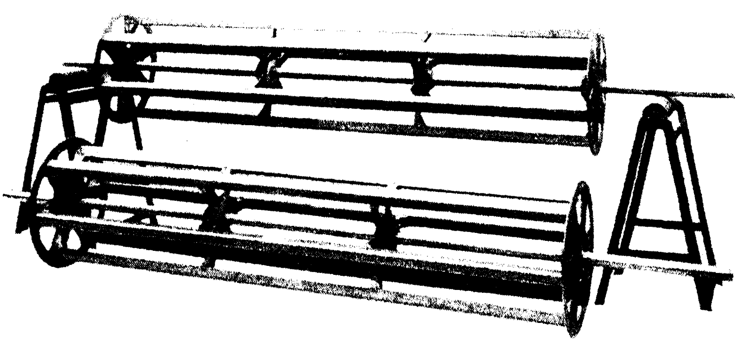


Fig. 3.

Facing p. 384

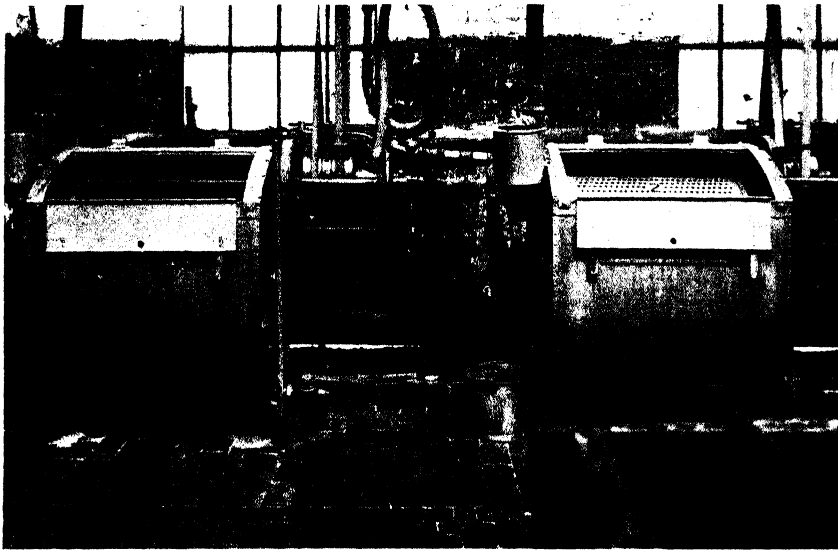


Fig. 4.

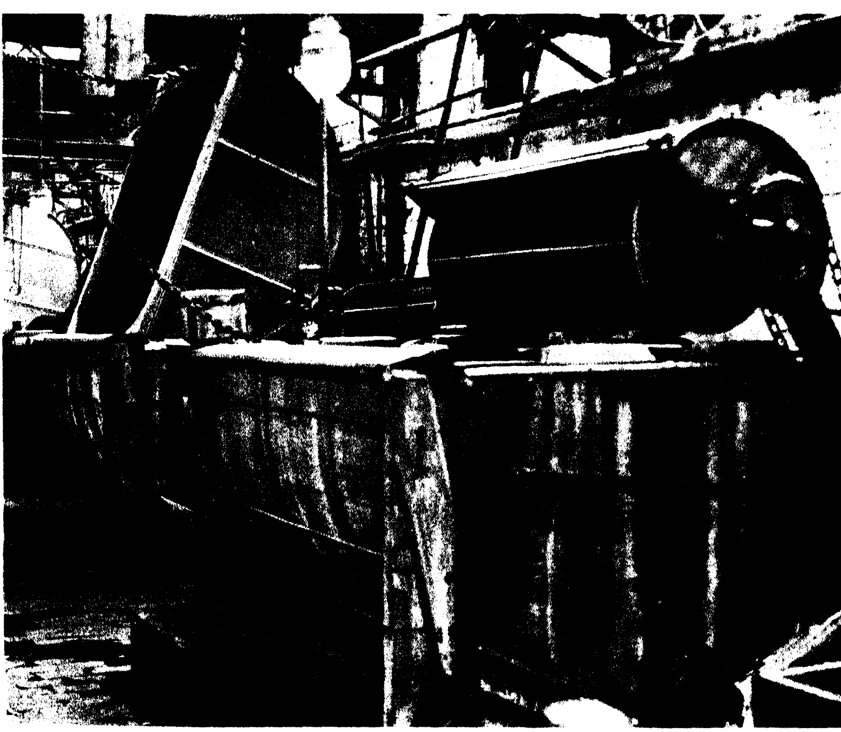


Fig. 5.

lined with Monel. With jiggers it is particularly useful to be able to clean up rapidly between batches since it may be necessary to dye several shades on the same machine during the day. This coupled with the rather awkward shape of the normal jigger beck call for a surface which can be easily washed down. Monel is also used for the rolls. Skein dyeing is carried out either by hand or by machines of the Gerber type. For the reel (Gerber) type, long becks are of course demanded. Some of these are of wood lined with Monel while others are in the form of all Monel tanks. A typical beck—constructed of 1/16″ thick Monel sheet—all joints welded, for use in the dyeing of artificial silk skeins shown in Fig. 1. This is 50′0″ long.

Monel in the form of tubes is widely used for the construction of heating coils for dye vats. Fig. 2 shows a coil constructed of 2″ outside diameter x 14 G. tube, suitable for heating 625 gallons of dye liquor from 50° F. to boiling point in 45 minutes. It will be noted that the coil is assembled by means of slip-on sleeves oxy-acetylene welded to the main parts.

Figures 3, 4 and 5 illustrate further the application of Monel.

Bleaching

Two classes of bleach liquor have to be considered. The first and most commonly used is the hypochlorite bleach now very generally used in the form of sodium hypochlorite. Tests on Monel with sodium hypochlorite solutions at atmospheric temperature showed negligible corrosion in solutions having concentrations of available chlorine below 3 gr. per litre. When the available chlorine concentration is increased to 4 gr. per litre, the corrosiveness of the solution is quadrupled, while at 7 gr. per litre, corrosion rates are ten times as high as at 3 gr. per litre. On the basis of these figures it has been the practice to recommend the use of Monel for holding hypochlorite solutions containing not more than 2½/3 gr. per litre of available chlorine. Practical experience during the past 15 years has demonstrated the soundness of these recommendations. In one artificial silk works using a large reel hank machine which was employed on both dyeing and bleaching and which over a particular period was in continuous use for white bleaching at about 3 gr. per litre, there was no evidence of any marking or pitting of the metal after two weeks' treatment. This firm, of course, took care to fill up the tank with water and soap immediately after bleaching and to obviate any rise in temperature of the solution due to the steam leaking into the heating coil. The continuous success of Monel in that particular works in reel type skein dyeing machines handling artificial silk has led to their standardising of Monel for all their machine linings.

So far as metals and alloys are concerned the particular difference between peroxide and hypochlorite bleaching solutions is the relatively non-corrosive nature of the peroxide solutions and their greater susceptibility to decomposition. Since peroxide solutions are practically non-corrosive their effects on metals are less important than the effects of metals on the solution.

According to Campbell* the factors influencing the stability of a peroxide bleach bath are temperature, hydrogen ion concentration (*p*H), type of alkalizing agent, the material being bleached, the water and the bleaching vessel. We are concerned principally with the last factor, and more especially with the metal or alloy of which it is constructed. It is known that if certain metal salts are added to the peroxide solution they increase the rate of decomposition. Both copper and iron are active in this respect, copper being more powerful than iron. However, this does not mean that contact of a peroxide solution with alloys containing copper necessarily accelerates decomposition. It is possible to estimate the effects of metals and alloys on peroxide bleach baths by exposing specimens to bleaching solutions, and

* *American Dyestuff Reporter*, Feb. 10th, 1936, p. 67.

determining the extent of decomposition after a given period of time as compared with a sample of solution containing no metal. In a preliminary test 100 volume hydrogen peroxide was found to retain its original strength after 24 hours, either in glass or in contact with nickel. Bleaching solutions containing about 10 grams per litre of hydrogen peroxide and 10 c.c. per litre of sodium silicate (*p*H 10-11) were made up in covered nickel, Monel and glass vessels. The ratio of exposed metal area to solution volume was 380 sq. cm. (59 sq. in.) per litre. This is comparable with the conditions in typical dyeing machines. The solutions were kept at about 185° F. for 80 minutes and then allowed to cool to atmospheric temperature and kept for about 17 hours, with the results noted in Table II, corrections being made for about 5 per cent. loss of volume by evaporation.

Table II. Rates of Decomposition of Peroxide Bleaching Solutions (containing 10 c.c. per litre of Sodium Silicate *p*H 10-11) in Monel, Nickel, and Glass Containers

		Glass Container		Nickel Container		Monel Container	
Time	Temperature	Peroxide Concn. in gr. per litre	Loss in Peroxide %	Peroxide Concn. in gr. per litre	Loss in Peroxide %	Peroxide Concn. in gr. per litre	Loss in Peroxide %
0 min.	185° F.	10·16	0	10·25	0	10·21	0
40 min.	185° F.	9·35	8	9·12	11	8·87	13
80 min.	185° F.	8·53	16	8·20	20	7·85	23
17 hr.	80° F.	7·62	25	7·28	29	7·05	31

Under these test conditions there was no important difference between the three vessels and it would seem safe to conclude that both nickel and Monel have a negligible catalytic effect on the decomposition of the peroxide bleaching solution. These tests are confirmed in practice. Thus in a plant processing cotton, cotton-rayon mixtures and rayon, all the bleaching and dyeing equipment is of Monel which has been in use for 10 years. The bleaching procedure involves a preliminary scour for 15 minutes at 175° F. using a mixture of pine oil, soap, and sodium silicate. The bleach bath contains 20 lbs. of sodium silicate and 3½ quarts of 100 volume hydrogen peroxide per 300 gallons of solution for 150 lbs. of goods which are bleached in a period of 1 to 2 hours at 180° F. The operator has had complete satisfaction from the Monel equipment for such peroxide bleaching as well as for dyeing.

The foregoing refers of course to peroxide baths as made up for bleaching and it is now common practice to purchase hydrogen peroxide as such. If, however, the peroxide is being prepared by mixing sodium peroxide with acid, then this mixing should be carried out in a crock or wooden tub and the peroxide solution only added to the alkaline solution or sodium silicate solution in the Monel-lined vessels.

Mercerising

Monel has been used in the construction of expander bars on account of its satisfactory strength and its high chemical resistance to the action of caustic soda solutions under all conditions of temperature, concentration, etc. In the impregnating machinery the caustic boxes have been lined with the metal and the mangle rollers have been covered with a Monel shell.

Monel finds considerable application in the auxiliary plant of a mercerising installation. The storage tanks with their cooling coils, if made in this metal, avoid contaminating the caustic soda by iron and they are also not subject to corrosion particularly at joints, seams and edges. Monel wire cloth in a variety of gauges and patterns may be obtained for the construction of strainers to remove cotton residues and the deposits of calcium carbonate which form when the liquors are not made up with soft water. Various patterns of filters

are used to remove the calcium carbonate precipitated during recauticisation. For filter presses Monel wire cloth filters with rubber gaskets can be used while the same material forms the filtering medium on continuous rotary filters of the immersed suction drum type. Very satisfactory behaviour has been recorded for Monel and nickel tubes in vacuum evacuators for caustic recovery.

Drying and Finishing Machinery

The ability of Monel to retain a bright readily cleaned surface, free from rust makes it particularly well adapted for the construction of steam drying cylinders in dry ranges alone or in conjunction with pad mangles, backstarching and coating ranges, etc. In padding ranges, where cloth impregnated with chemicals goes to be dried, the scope of the machine is widened by a corrosion-resistant material, although the limits to the resistance of Monel given in the first part of this account must be observed. Not only on the drying cylinders but also in filling and coating operations where corrosion and abrasion resistant doctors are required, Monel may be the most appropriate material.

There are to-day, however, many new finishing processes of a highly specialised kind as for instance in the artificial leather, book-cloth, non-crease treatments, water-proofing and similar industries. Chemically active materials may be incorporated in the coatings or may be used for treating the cloth in other ways. These processes may call for very special properties in the chemical behaviour of the materials from which the plant is constructed, and here again Monel seems to offer promise of utility.

Perforated cylinders of Monel as steaming rolls for the cloth in the decatising process have been used with success.

For the special treatment of silk, tin-weighting ranges built on the lines of the automatic roller dyeing machines, with boxes, rollers and fittings made from Monel, have been successfully put into operation.

With the exception of the rollers, doctors and colour boxes, few of the metal parts of the printing machine and hot flux come into contact either with the cloth or with the chemicals printed on it before the cloth reaches the dry condition. Probably the machines connected with printing in which Monel is most widely used are the open soapers. Monel boxes, guide rollers and paddles built from the metal increase the variety of chemical treatments that can be carried out in this type of machine.

Inconel

This alloy became commercially available as a product of the International Nickel Co. in 1931 and is now being rolled in Great Britain. This material can really be described as a stainless nickel since it contains 80 per cent. nickel, 14 per cent. chromium, and 6 per cent. iron. It was soon found to possess good resistance to the corrosive action of several chemicals used in the wet processing of textiles. While it is too soon to estimate how important a place Inconel will occupy in the textile industry, it does seem certain that it has a definite future before it. The reason for this is that Inconel combines with its resistance to wool dyeing liquors the ease of fabrication and the reliability of soldered or welded joints which have characterised Monel.

It will be agreed that if equipment, however satisfactory from the point of view of the dye liquor, has to be too frequently in the hands of the engineering department for repairs to welds which have failed by corrosion, much of the benefit will be lost. The experience of firms utilising some of the Austenitic stainless steels has not been entirely unattended by difficulties in maintaining the equipment in good repair. One firm which has already had experience in this direction has now had in service for several months an Inconel dyeing machine, which is very satisfactory from the engineering standpoint.

Table III. Mechanical Properties of Inconel.

	Tensile Strength (tons/sq. in.)	Yield Point (tons/sq. in)	Elongation (per cent.)
Sheet and Strip—			
Annealed	35-40	13-15	45-55
Rod—			
Annealed	35-40	13-15	45-55
Cold Drawn	45-50	35-40	20-30
Wire—			
Annealed	35-40	13-15	45-55
Spring temper	78-85	—	—

In passing it might be noted that Inconel is considerably stronger than mild steel and is at the same time ductile as can be seen from Table III depicting its mechanical properties. Inconel is white in colour and can if necessary take a high and durable polish. Table IV summarizes tests recorded in America of the effect of Inconel on several sensitive dyestuffs, and it will be noted that no important off-shade effects were produced.

Table IV. Effects of Inconel on Several Sensitive Dyestuffs.

Dyestuff	Colour Index No.	How Dyed	Effect of Inconel
Alizarine Yellow 2G	36	Top Chrome	Slightly redder and brighter
Acid Alizarine Violet	169	Top Chrome	Practically no effect
Eriochrome Blue Black R ...	202	Top Chrome	Slightly greener and duller
Eriochrome Black T	203	Top Chrome	Practically no effect
Eriochrome Red B	652	Top Chrome	Slightly yellower
Alizarine Cyanine Green ...	1078	Top Chrome	Practically no effect
Anthraquinone Violet	1080	Top Chrome	Slightly brighter
Alizarine Sky Blue B	1088	Top Chrome	Practically no effect
Monochrome Brown BC Conc. S	—	Top Chrome	Very slightly yellower
Wool Fast Orange GA	—	Top Chrome	Very slightly yellower
Acid Anthracene Brown B ...	—	Top Chrome	Practically no effect
Metachrome Red G	—	Top Chrome	Practically no effect
Metachrome Olive GG	—	Top Chrome	Practically no effect
Eriochrome Grey SGL	—	Top Chrome	Practically no effect
Metanil Yellow	138	Acid	Slightly greener
Azo Yellow	146	Acid	Practically no effect
Azo Rubine	179	Acid	Very slightly bluer
Xylene Light Yellow	639	Acid	Practically no effect
Alizarine Saphirol B	1054	Acid	Practically no effect
Alizarine Rubinol	1091	Acid	Practically no effect
Alizarine Direct Blue A2G ...	—	Acid	Slightly greener and brighter
Wool Fast Orange GA	—	Acid	Slightly redder
Alizarine Irisol R	—	Acid	Very slightly greener

Laboratory corrosion tests show that Inconel is practically completely resistant to corrosion by the mixtures of acetic acid and sodium dichromate encountered in the chrome dyeing of wool. These tests are confirmed by actual practice. Inconel appears to be about five hundred times as resistant as Monel metal to corrosion by diazotizing solutions. The tests carried out were especially severe, since there was no dyestuff present to react with the nitrous acid and thereby cut down the amount available for corrosion of the metals.

It is the author's hope that this rather brief survey of the properties of Inconel has not been entirely without interest. There is certainly no doubt that it does offer something exceptional in the way of resistance to corrosion allied to mechanical strength and ready workability.

Nickel Clad Steel

This product, as the name implies, is one which consists of a steel plate carrying nickel cladding on one or possibly both surfaces. It is now being produced in this country and from the point of view of the textile engineer, seems

likely to be of particular interest for use in connection with peroxide bleaching. Normal nickel clad steel is rolled with 10 per cent. cladding on one side, i.e. nickel clad plate having an aggregate thickness of ¼″ will carry 0·025″ of nickel on one surface. Thicknesses between 3/16″ and 1¼″ are in normal production.

In welding nickel clad steel the steel side is welded with steel and the nickel side is then welded with nickel filler rod so as to give an unbroken nickel surface on the face which is exposed to the processing solutions. Nickel clad steel is essentially a hot rolled plate product. As mentioned above the peroxide bleaching kier seems to be a logical application for nickel clad steel.

A report from America states that about a year ago a Southern cotton mill installed a peroxide bleaching kier made from nickel clad steel for the bleaching of cotton thread in packages. The user recently reported that the nickel clad steel was satisfactory in every respect. The yarn is given a preparatory boil in a solution containing castor oil and soda ash at 200° F. The peroxide bleach itself is made up with 100 volume hydrogen peroxide and sodium silicate and bleaching is carried out at 180° F. The bleached yarn packages are given a preliminary drying in a Monel centrifugal extractor.

The reference to nickel clad steel has only been brief but may have been sufficient to indicate some of the potentialities of this material. It is essentially a product for use on relatively large and heavy equipment where the service is such as to demand thick plate to carry high pressures or heavy loads. For such conditions by the use of nickel clad steel the corrosion resistance of nickel is secured just where it is wanted and the use of nickel at a high price merely to secure strength or rigidity is avoided.

In conclusion, the author would like to mention that in the section dealing with Monel, he has drawn to some extent on the writings of Mr. Schofield of Manchester, while in connection with Inconel, he is indebted to the data published by Mr. La Que of the Research and Development Department of the International Nickel Company of Canada.

A Joint Meeting of the Lancashire Section of the Textile and the Oldham Technical Association was held at the Technical College, Oldham, on November 11th, 1937. Mr. F. P. Slater, M.C., M.Sc., M.A., F.T.I., gave a lecture on "The Textile Institute's Scheme for Standardisation in Textiles."

Mr. Slater opened his lecture with proofs of the need for testing textile materials under controlled conditions. With the aid of slides he demonstrated the variation in strength of cotton yarns with the relative humidity of the atmosphere. Unless the conditions are regulated within comparatively narrow limits the results of tests can be actually misleading. He then dealt more generally with the unification or standardisation of testing methods, to which he said the Institute at first proposed to confine its activities. Despite the great care exercised in drawing up the scheme, it has been misread and misinterpreted in some quarters. He wished emphatically to state that there was to be no attempt to standardise fabrics. He was quite convinced that unless the various sections of the textile industry followed the lead of the engineering and other industries in adopting standards, standardisation would be forced upon them by interests which do not possess the necessary technical knowledge and a state of chaos would be the result. The Institute, by virtue of its Royal Charter, was the body to undertake this work, because it is the only organisation supported by the technically qualified men in every branch of the textile industry. Mr. Slater described the machinery it was proposed to set up, emphasizing that it provided for complete control by the trade itself. In the main committee (i.e. the Representative Advisory Committee composed wholly of men in the textile industry) would rest the power of veto over proposals not considered to be to the interest of the industry as a whole. He showed how it would be linked up with the British Standards Institution which is the only organisation in this

country officially empowered to issue standards. By agreement with this Institute the British Standards Institution undertook not to issue standards which have not been discussed by the standardisation committees of the Textile Institute.

At Mr. Slater's request the General Secretary of the Textile Institute dealt very briefly with the financing of the scheme, showing clearly that no firm would find its contributions burdensome.

The Chair was ably taken by Mr. B. Shore, Wh.Ex., who invited questions from the large audience, which were duly answered by Mr. Slater and Mr. Robinson.

Irish Section

Meeting held at Belfast, Thursday, 28th October, 1937, to discuss the Textile Institute's Standardisation proposals. The meeting was addressed by Mr. Frank Nasmith, Vice-President and Hon. Secretary of the Institute, Mr. C. Le Maistre, C.B.E., of the British Standards Institution, and Dr. W. H. Gibson, O.B.E., Director of Research, Linen Industry Research Association.

Mr. Frank Nasmith, Vice-President and Hon. Secretary of the Textile Institute, opened with a brief description of the aims and objects of the Institute. Composed of members of every branch of the Textile Industry, with the object of furthering the progress of textile technology, the Institute is the only fully representative body. The objectives of the founders were education, publication and standardisation. These were embodied in the Royal Charter of 1925 and the Institute will fail in its duty if it does not implement the terms of that document.

The Institute Council, realizing the crying need for standardisation, set up about 2 years ago a committee to deal with the Unification of Testing Methods. This Committee has concluded the preliminary stages of its work and out of it will arise the Representative Advisory Committee. This in time will form the nucleus of the Textile Section of the British Standards Institution. The Representative Advisory Committee will deal with all work connected with standards and appoint the necessary sub-committees to deal with specific duties. It will receive the reports of these sub-committees, give the necessary publicity to tentative specifications and methods of test, and finally collaborate with the British Standards Institute in the official promulgation of standard specifications.

Mr. C. Le Maistre, C.B.E., of the British Standards Institution, dealt with the Textile Institute's Scheme in the light of his 35 years' experience in standardisation. He pointed out that while the scientific research worker seeks the complete confirmation of his work before publication, even if much time is thereby absorbed, the administrators of standardisation realize that delay must be avoided as far as possible. Standardisation unifies specifications in general practice without waiting for perfection, and by periodic review and revision embodies improvements which experience and research show to be practicable and not too costly.

Industrial standardisation covers an immense field. Most of the British Standard Specifications are intended to guide the technically competent purchaser, who acts for a branch of industry which uses the products of another trade. Such specifications safeguard manufacturers against unfair competition since sub-standard materials or appliances can be rejected. The specifications cover personal safety, as for example, lifting gear, electrical equipment, steam boilers, etc.

The British Standards Institution has always considered that its prime duty, before producing any specification, is to secure the consent of all interests concerned. This is the corner stone of the movement and the reason for the country's confidence in the British Standards Institution. There must be no coercion of any description or any arbitrary imposition of standards. The

British Standards Institution is thus a central co-ordinating body, which maintains contact between the various interested branches of industry. Every industry establishing a section for itself under the aegis of the British Standards Institution has complete technical autonomy under the general Council, which is solely concerned with policy and adherence to the fundamental agreed principles. The Representative Advisory Committee to be appointed by the Textile Institute will eventually become the Textile Section of the British Standards Institution and take its place alongside the three existing sections, engineering, building and chemistry.

The international aspect of standardisation is one of considerable interest to the Textile Institute. The British Standards Institution is already in direct touch with the International Standards Association and with the national standardising bodies in many European countries, the Dominions and America.

What possible hope would there be of an ordered development of standards unless there be one central organisation in each country through which they are promulgated, yet in U.S.A., the home of standardisation, there are numerous organisations drawing up standards. Even some of the great American stores have so-called Bureaux of Standards. However, the American Standards Association, the nationally organised Body, is doing its best to unify and coordinate these various efforts.

The Textile Institute will, it is hoped, look back with considerable satisfaction on its decision to throw in its lot with the British Standards Institution, the national centre. Not only is it following the advice and wishes of all the Imperial Conferences but it is helping to make the National standards more authoritative and so more useful to the Textile Industry. Finally the fact may again be emphasised that in joining the British Standards Institution it is the Textile Institute which will govern the work and determine its scope, the British Standards Institution placing its staff and specialised experience and particularly its central co-ordinating influence at the disposal of the Institute.

Dr. W. H. Gibson, O.B.E., Director of the Linen Industry Research Association, stressed the need for uniformity in the testing of textile materials. From the beginning the customer has always required some assurance that he was getting what he wanted and from this the practice arose of requiring deliveries to conform to a pattern. This is the simplest form of specification. The customer cannot rely on a mere inspection to show him whether deliveries do actually conform to pattern. With the progress of science and its application to textiles it has been open to the customer to apply tests, which are becoming ever more numerous and more searching.

The customer, however, has had to agree with the manufacturer in regard to the tests applied and the standard of performance in the tests which should be reached in each case. The customer is not a textile expert but he knows what his requirements are. The manufacturer, who is a textile expert, knows what is possible in manufacture to meet the requirements of the customer and what tests can reasonably be met. Many years ago it became apparent that if distrust and endless disputes were to be avoided it was necessary to have separate and impartial organisations to carry out the testing work whose verdict could be taken as an honest one and acceptable both to the manufacturer and the customer. By this process the modern textile specification was slowly evolved and it became customary to submit various textiles to a recognised testing house for test according to recognised specifications, which gave instructions on the tests required to be made, the manner of making them and the results required. These specifications were adopted at first by large users of textiles such as Government Departments and public utility companies, who required material to be satisfactory for a certain purpose, but who were not much concerned with its appeal to the individual taste.

For this reason, to begin with, most specifications were concerned with physical or mechanical tests as it was mainly a matter of whether the material was strong enough for the purpose or not. The adoption of such tests and satisfactory performance of them when adopted is not such a simple matter as it appears at first sight. There are some very important conditions, among which are: —

1. The proper conditioning of the sample to be tested, and the conditioning of the atmosphere in which the test is to be done.
2. The design of the machine on which the tests are to be made.
3. The correct manipulation of the testing machine.

Thus, tests are comparative rather than absolute and it is particularly dangerous to draw conclusions about fabrics which differ from each other in structure or finish.

The advent of large industrial research associations about 18 years ago has had a considerable influence on this question of testing. Research can be done on methods of testing as well as on other parts of the textile industry, indeed, since science is measurement, progress in any branch of textile science is dependent on testing and methods of testing. All the large Research Associations have been bound to investigate very fully the problems of testing. Their work has resulted in a steady improvement in testing, greater precision in existing tests, and the development of new tests.

The work of Research Associations has done more than this, it has developed to a remarkable degree the use of tests in process control, so much so, that this use of tests is more valuable and more vital to the textile industry than the original use as a guarantee that the requirements of the purchaser were being met. This has led to a much wider development of private research and testing departments by individual firms, where the primary object is to maintain the quality of the firms' products by means of process control through testing. The state of affairs now is that there is everything to be gained and nothing to be lost by unification of testing and testing methods. The two uses of testing, for process control and for specification work, must be reconciled. Unnecessary tests and the duplication of testing must be avoided. This can be secured by the centralisation of the control of testing in strong, responsible, representative and competent hands.

Steps must then be taken to raise the competency of all institutions or departments undertaking the testing of textiles to an approved level. So far as the Linen Industry is concerned, it has relied upon the Linen Industry Research Association for scientific and technical advice. The L.I.R.A. has always recognised the value of the Textile Institute as the general body for the promotion of knowledge in the textile industries. Under an arrangement with the L.I.R.A. all our members under a form of group membership are members of the Textile Institute.

This new standardisation scheme will be carried out by the Textile Institute. The work will be in the hands of a group of people who are reliable, responsible, and to a due degree representative of our industry. All the important technical issues here touched upon will be in safe hands and the industry can be assured that the advice of the Research Associations will be sought and followed. At the same time, the organisation dealing with testing to be set up by the Textile Institute will form part of the British Standards Institution and in this way will be recognised officially as the supreme authority in regard to Standardisation and Testing in the United Kingdom.

Scottish Section

The Scottish Section of the Textile Institute spent a very interesting day in the Border country on Saturday, 16th October, 1937. In the morning more than a dozen members, mainly from the jute and linen trades, visited the Scottish Woollen Technical College and were much interested in demonstrations of the teaching methods used in the College. Some of them were particularly curious in comparing the spinning of wool fibre with the methods used in their own industries, and expressed themselves as very highly pleased with the lucidity of the explanations given by the College Staff. They were also interested in the methods used for imparting "colour consciousness" to students.

After lunch at the Douglas Hotel, the party, strengthened to about 35 by the addition of local members and College students, proceeded by private S.M.T. omnibus to Jedburgh where arrangements had been made for them to see over the factory of North British Rayon Limited. Five guides took seven visitors each and not only explained all the processes fully but answered the numerous questions put to them by experts from other branches of textiles. After tea at the Royal Hotel, Jedburgh, Mr. Mullineux, works manager of the factory, gave a short lecture on Rayon Manufacture and, assisted by Dr. Pitter, chief chemist at the factory, answered further questions. The Institute members left feeling they had learned as much about rayon manufacture as an outsider to the industry could know and well pleased with the welcome given them in the Scottish Borders.

Midlands Section

On Wednesday, 20th October, Dr. Edwin Wildt, F.T.I., Chairman of the Midlands Section Committee, presided at a well attended meeting of the Section at the University College, Department of Textiles, Nottingham, when Dr. J. B. Speakman, F.I.C., F.T.I., gave a most interesting and instructive lecture on "Recent Research on Wool and its Industrial Application."

Dr. Speakman discussed briefly the chemical structure of wool, indicating how the behaviour of the fibres in various processes could be explained in terms of the salt and sulphur linkages between the peptide chains. When dry, the interior of the fibre is inaccessible to molecules larger than the *n*-propyl alcohol molecule, thus limiting the activities of the organic chemist. Use has, however, been made of this fact in modern methods of imparting an unshrinkable finish to wool. By using chlorine as gas, as in the Wool Industries Research Association's process, or by using sulphuryl chloride in white spirit, as in Hall's process, attack is restricted to the surface of the fibre and undue damage is prevented.

When the fibre is swollen in water, its accessibility to chemical compounds is increased, and the salt and sulphur linkages may be modified to give useful practical results. Breakdown of the salt linkage is, for example, a primary necessity in acid dyeing processes, but the latter are also aided by sulphur linkage breakdown, which becomes significant at temperatures above 45° C. Sulphur linkage breakdown is also responsible for the existence of a critical temperature in milling and peroxide bleaching, the temperature being again 45° C. in both cases. Similarly, the fact that disulphide bond attack increases rapidly at *p*H values above 10, at ordinary temperatures, is the reason why *p*H 10 is critical in milling and peroxide bleaching. The reactivity of the sulphur linkage in animal fibres was also discussed in connection with the sulphur dioxide bleach, the action of light on wool, and crabbing and blowing processes.

Finally, it was argued that since existing finishing processes are based on the properties of salt and sulphur linkages, new processes should become possible with the synthesis of new linkages between the peptide chains. One example is, of course, to be found in the fact that permanent set is due to the synthesis of

such new linkages, but examples of four other types of bond which have been synthesised were given.

In proposing a vote of thanks to Dr. Speakman, Mr. A. J. Hall referred to his lecture as being valuable light in the darkness of those struggling for information on the inner structure of wool fibres.

The meeting closed with a vote of thanks to the Chairman proposed by Mr. S. G. Blackburn of Nottingham.

Correspondence

THE STRUCTURE OF KERATIN FIBRES

To the Editor

Sir,

In two surprising communications[1, 2] that have appeared within the last few months* in this *Journal* and elsewhere W. Harrison repudiates our interpretation of the molecular structure and properties of the keratin fibres. Readers of the original papers on this subject[3] and on the X-ray interpretation of protein structure in general[4] will no doubt have noted the incomplete presentation both of fact and theory that marks these two communications, but for the benefit of those who have not followed closely the developments in this field, a brief statement on our part may be found useful in assessing which of the two views, Harrison's or ours, is the more worthy of consideration.

Harrison's arguments fall roughly under three heads:—(1) "It appears certain that the elastic properties of hair and wool are dependent on the cuticle."[1] "There can be no doubt therefore, that the different physical and chemical properties of the cuticle and the cortex are responsible for most of the phenomena met with in the supercontraction and permanent set of keratin fibres."[2] (2) He suggests that the change from the α- to the β-type of X-ray photograph which occurs when keratin is stretched need not be due to a straightening of normally folded polypeptide chains, but is more simply and more reasonably explained as due to a change in crystal form from orthorhombic to monoclinic (*sic*) by a process of shearing and reducing the distance between the polypeptide chains. (3) He refuses to believe that β-keratin can be an elongated stereo-isomer of α-keratin, since it can be produced during the changes leading to supercontraction, or even without stretching the fibre.

Under these three heads we should like to make the following remarks:—

(1) There are various indirect objections to this hypothesis of Harrison's—the climax of his reasoning—but there is one direct answer which disposes of it almost in a word. The characteristic elastic properties of the keratin fibres cannot possibly bear more than an insignificant relation to the cuticle, because they are shown by descaled fibres, strips of horn, porcupine quill, etc., cut from the interior, and also by isolated cortical cells. A detailed discussion of the X-ray photographs, long-range elasticity, relaxation, supercontraction and permanent set of the cortical cells is in preparation[5]—they all remain substantially unchanged when the fibres are disintegrated ; but preliminary accounts have already appeared[6] which were in Harrison's hands. It should be stated too, in fairness to the present writers, that the gist of these more recent results was communicated to Harrison privately.

(2) The crystallographic change from α- to β-keratin proposed by Harrison might appear plausible were it not for the fact that it involves a 50 per cent. increase in density! By experiment, the densities of unstretched and stretched keratin fibres are approximately the same—indeed, the most recent estimates indicate that, if anything, stretched fibres are slightly the less dense. It also offers no reason whatsoever for the *long-range* elasticity of keratin, since it could

* The delay in publishing this reply is due to the absence of one of us abroad.

NOTICES: INSTITUTE MEETINGS

Wednesday	1st December	*Manchester*—2.15 p.m. Meeting of Diplomas Committee, at the Institute.
Tuesday	7th December	*Manchester*—3 p.m. Meeting of Publications Committee, at the Institute.
Wednesday	15th December	*Manchester*—3 p.m. Meeting of Council, preceded by Meeting of Finance and General Purposes Committee, at the Institute.

Lancashire Section

Thursday	9th December	*Manchester*—7.30 p.m. Lecture (Jointly with Manchester College of Technology Textile Society): "Mechanical Irregularities and their Effect in Fabric Processing" by Mr. E. Farrell, M.I.Mech.E., at the College of Technology.
Tuesday	14th December	*Manchester*—7.30 p.m. Lecture and Discussion (Jointly with British Association of Managers of Textile Works): "Standardisation and Unification of Testing Methods," by Dr. E. F. Armstrong, F.R.S., B. H. Wilsdon, M.A., B.Sc., and Mr. A. W. Bayes, M.Sc., A.T.I., at The Athenaeum.
Saturday	18th December	*Manchester*—6.30 to 11.30 p.m. Social Evening at Engineers' Club. Tickets, 5s. each.

Midlands Section

Friday	10th December	*Nottingham*—7.15 p.m. Annual Dinner, at Victoria Station Hotel. Tickets, 7s. 6d. each.

Yorkshire Section

Monday	13th December	*Bradford*—7.30 p.m. Lecture (Jointly with Bradford Textile Society): "Standardisation in the Textile Industry," by Dr. E. F. Armstrong, F.R.S., Mr. B. H. Wilsdon, M.A., B.Sc., and Mr. A. W. Bayes, M.Sc A.T.I., at Midland Hotel.

London Section

Monday	13th December	*London*—Lecture: "Modern Knowledge of the Structure of the Wool Fibre in Relation to Technical Processes," by Dr. J. B. Speakman, F.I.C., F.T.I.

Other Organisations

Batley and District Textile Society—

Thursday	2nd December	*Batley*—7.30 p.m. Lecture: "The Beauty of Colour and Textile Printing," by Mr. N. Band, at Technical College.

Blackburn Textile Society—

Friday	3rd December	*Blackburn*—Lecture: "Developments in the Northrop Loom," by Mr. H. de G. Gaudin.
Friday	17th December	*Blackburn*—Lecture: "Warp Dyeing," by Mr. J. L. Lishman.
Saturday	18th December	Visit to Messrs. Newman's Slipper Works, Griffin Mills, Blackburn.

Bolton and District Manager, Carders, and Overlookers' Association—

Friday	3rd December	*Rochdale*—8 p.m. Lecture: "Cotton Waste Carding—Future Developments," by Mr. R. Stansfield, at White Swan Hotel.
Saturday	4th December	Visit to Manchester Chamber of Commerce Testing Houses and Royal Exchange.
Friday	10th December	*Bolton*—Talkie Film Lecture: "Bakelite—The Material of Infinite Uses." Messrs. Bakelite Ltd., London.

Bradford Textile Society—

Wednesday	8th December	Evening Visit to Messrs. English Electric Co. Ltd., Bradford.
Monday	13th December	*Bradford*—7.30 p.m. Lecture: "Standardisation and Unification of Testing Methods," by Messrs. E. F. Armstrong, F.R.S., B. H. Wilsdon, M.A., B.Sc., A. W. Bayes, A.T.I., jointly with British Standards Institution, Textile Institute, and Society of Dyers and Colourists, at Midland Hotel.

Burnley Textile Society—

Tuesday	7th December	*Burnley*—7.30 p.m. Lecture (Film-illustrated): "Bakelite: the Material of Infinite Uses," by a representative of Bakelite Ltd., at Mechanics' Institute.
Saturday	11th December	Visit to Broad Oak Print Works, Accrington.

Colne and District Textile Society—

Saturday	4th December	Visit to Messrs. Thos. Hardman & Sons, Ltd., Bury.
Friday	17th December	*Colne*—7.30 p.m. Lecture: "The marketing of Silk and Cotton Furnishing Goods," by Mr. Sloan, of Messrs. Lewis's Ltd., Manchester, at Technical School.

Cumberland Textile Society—

Thursday	2nd December	*Carlisle*—7.30 p.m. Lecture: "General Aims and Organisation of the British Cotton Industry Research Association," by Dr. Toy, at Technical School.

Derby Textile Society—

Tuesday	7th December	*Derby*—7.30 p.m. Lecture: "Knitted Fabrics," by Mr. W. E. Boswell, at Technical College.
Saturday	11th December	Visit to Messrs. Wm. Frost & Sons Ltd., Macclesfield.

Dewsbury Textile Society—

Saturday	4th December	Visit to Messrs. Critchley, Sharp and Tetlow Ltd., Cleckheaton.

[P.T.O

Halifax Textile Society—

Monday	6th December	*Halifax*— 7.30 p.m. Lecture: "Russia and the Textile Industry," by Coun. E. Thornton, at White Swan Hotel.

Haslingden District Textile Society—

Thursday	2nd December	*Haslingden*—7.45 p.m. Lecture (Lantern-illustrated): "The Lighting of Textile Mills," by Mr. A. D. S. Atkinson, at Grammar School.
Saturday	4th December	Visit to Britannia and Alma Mills of Messrs. J. H. Birtwistle & Co., Ltd., Padiham.
Thursday	16th December	*Haslingden*—7.45 p.m. Lecture: "Woollen Carding and Spinning," by Mr. C. Sugden, at Grammar School.

Huddersfield Textile Society—

Monday	13th December	*Huddersfield*—Lecture: "Variability in Woollen and Worsted Carding," by S. Townend, Ph.D.

Keighley Technical College—

Monday	13th December	Visit to Messrs. Geo. Hattersley & Sons Ltd., Keighley.

Leicester Textile Society—

Friday	10th December	*Leicester*—7.30 p.m. Lecture: "World Tour," with Films, by Mr. A. W. Swann (Ladies' Evening).

Oldham Technical Association—

Tuesday	14th December	*Oldham*—7.30 p.m. Film: "R.M.S. 'Queen Mary'," by Mr. H. R. Baldry, at Technical College.

Rochdale Cotton Spinning Mutual Improvement Society—

Tuesday	7th December	*Rochdale*—8 p.m. Lecture (Lantern-illustrated): "Speed Frame," by Mr. Tetlow, at Barlow Street.
Tuesday	14th December	*Rochdale*—8 p.m. Lecture (Lantern-illustrated): "Modern Winding Methods," by Mr. E. L. Dixon, at Barlow Street.
Tuesday	21st December	*Rochdale*—8 p.m. Lecture: "Cotton Trade Prospects," by Mr. B. Robinson, at Barlow Street.

Shipley Textile Society—

Monday	13th December	*Shipley*—7.30 p.m. Lecture: "Factors that Influence Shrinkage and Appearance of Fabrics," by Mr. F. H. W. Bennett, at Technical Institute.
Saturday	18th December	Visit to Messrs. Hailwood and Ackroyd, Morley.

Todmorden Textile Society—

Monday	6th December	*Todmorden*—Lecture: "Metal Spraying," by Mr. H. Townend. (Illustrated by cinematograph).

Guild of Calico Printers', Bleachers', Dyers', and Finishers' Foremen—

Saturday	18th December	*Manchester*—7 p.m. Lecture: "The Finisher's Point of View," by Mr. F. A. Rushton, at Thatched House Hotel, off Market Street.

bring about no more than a negligible elongation of the *long, oriented* crystallites that the properties of the fibres demand. To overcome these difficulties, Harrison makes the further suggestion[2] that " the constant density can only be accounted for by assuming some change in the other constituents of the fibre." What other constituents? To cancel out a 50 per cent. increase of density in those more perfectly organised parts of the fibre which give rise to the X-ray " fibre photograph "—and again it must be emphasised that these same photographs are given by the cortical cells—it would be necessary to postulate a considerable proportion of some constituent whose density on stretching falls correspondingly. It will be sufficient to await the discovery of such a constituent, or in fact of any important proportion of a constituent with properties substantially different from the main properties of the fibres and their cortical cells, before taking up this matter further. In the meantime the hypothesis we have proposed, that of the unfolding of folded polypeptide chains on stretching, the grid-like structure of the keratin complex, the breakdown of cross-linkages of the grid on " relaxation," and the further folding on supercontraction or the re-building of cross-linkages on permanent set, is at least consistent with the facts, and serves to co-ordinate an immense mass of experimental data, not merely in the field of the keratins, but in that of the proteins in general.

(3) The production of keratin in the β-form by methods which appear not to involve stretching—squeezing laterally *does* involve stretching—is simply one example of the general mechanism of protein denaturation.[7] If we heat any " globular " protein there is a liberation of polypeptide chains, some of which aggregate into regular bundles analogous in structure to β-keratin ; and here, of course, there is undoubtedly an elongation of a proportion of the molecules without stretching the system as a whole. We must protest against the one-sided version of our interpretation that Harrison has put forward, for we have already discussed at length the points he raises in this connection. It is neither possible here nor necessary to do this again, but we should like to repeat that the keratin fibres appear to be built of a continuous range of chain-bundles of varying size and degree of organisation. The regular X-ray patterns and the phenomena of permanent set are associated more closely with the better organised (or " crystalline ") regions of the fibre structure, as would be expected, while the phenomena of supercontraction are associated more closely with the less organised regions. It is possible to set parts of the fibre in the elongated form while other parts are still capable of contracting, or even of super-contracting. Generalised setting of the fibre substance follows only on more prolonged steaming in the stretched state: the initial rapid setting of the more crystalline regions produces only " temporary set " and is insufficient to counteract contractile power still remaining if the free fibre is afterwards again exposed to steam. Thus it is that when a hair that has been exposed for a short time in the stretched state to the action of steam is caused to contract, the β-photograph persists but is found to be *disoriented* after contraction, because of the necessity of accommodating contractile and non-contractile parts in parallel. If the stretched fibre has not been exposed to steam, the β-photograph maintains its orientation during contraction but is gradually replaced once more by the α-photograph.

There are two main reasons why a β-photograph should be observed *on treatment with steam or boiling water after breakdown of the cross-linkages of the grid*—supercontraction can be produced without the appearance of a β-photograph, it should be noted. One is the " statistical effect " common to denaturation in general, whereby on the breakdown of a specific folded configuration of polypeptide chains a proportion of the latter will form fully-extended bundles giving an interpretable X-ray photograph, while the remainder take up all sorts of irregularly folded configurations which cannot be expected to give such a photograph. We see a similar effect when rubber is " frozen " and here again,

without stretching, it is possible to obtain the photograph of stretched rubber, which without doubt must be ascribed to fully-extended polyprene chains. The second reason is that the violent contraction of the less organised, and therefore more contractile, parts of the fibre tends to increase the perfection, if not actually to augment the number, of the extended chain-bundles ; that is, the better organised parts, since these are in a specially favourable state of aggregation once the linkages stabilising the α-configuration have been broken down. This is a phenomenon that we have investigated experimentally and called " differential supercontraction." Myosin shows the effect in still more striking fashion. In every case, though there is no stretching of the system as a whole, there is a temporary development of tension, and the obvious inference, in view of the indications of the X-ray photographs, is that certain parts have contracted at the expense of parts that have been oriented or stretched. It is only the latter which would be expected to give a regular X-ray photograph, and it seems to us hardly reasonable to expect a new regular X-ray photograph for the supercontracted state.

To continue the argument further with the accumulated evidence from X-ray and related studies of other proteins would be merely to repeat again what has already been written in other journals. The X-ray interpretation of keratin is now only part of the interpretation of a whole group of substances, and they stand or fall together. The isolated muscle protein myosin, for instance, has X-ray and elastic properties remarkably similar to those of the supercontracting form of keratin,[8] and there is no question here of invoking any interplay between the properties of cuticle and cortex, or of postulating " other constituents." If, as Harrison contends, our ideas on keratin are wrong—we are not, of course, maintaining that every minute detail is right, and every subsidiary hypothesis—it still remains to be shown how they are wrong, and the correct explanation must still be part and parcel of the interpretation of all proteins.

Harrison has neither shown we are wrong nor has he put forward any such explanation, though surely we have a right to ask for one in exchange for ours. The most fundamental property of the many beautiful properties of keratin is that it is an *oriented* system with a potential range of elasticity of up to 300 per cent. If our explanation of this and so many other things is erroneous, what *is* the explanation?

Textile Physics Laboratory,
University of Leeds.
November 16th, 1937.

W. T. Astbury.
H. J. Woods.

REFERENCES

[1] W. Harrison, *J. Text. Inst.*, 1937. **28**, P110.
[2] W. Harrison, *Chem. & Ind.*, 1937, **56**, 731.
[3] W. T. Astbury and A. Street, *Phil. Trans. Roy. Soc.*, A 1931, **230**, 75 ; W. T. Astbury, and H. J. Woods, *ibid.*, A 1933, **232**, 333 ; W. T. Astbury and W. A. Sisson. *Proc. Roy. Soc.*, A 1935, **150**, 533.
[4] W. T. Astbury, Cold Spring Harbor Symposia on Quantitative Biology, 1934, **2**, 15 ; Kolloid-Z, 1934, **69**, 340 ; *Nature*, 1926, **137**, 803 ; *Chem. Weekbl.*, 1936, **33** 778 ; *J. Text. Inst.*, 1936, **27**, P282.
[5] H. J. Woods.
[6] H. J. Woods, *Proc. Leeds Phil. Soc.*, 1936, **3**, 132 ; W. T. Astbury, *J. Text. Inst.*, 1936, **27**, P282,
[7] W. T. Astbury and R. Lomax, *J. Chem. Soc.* 1935, 846 ; W. T. Astbury, S. Dickinson, and K. Bailey, *Biochem. J.*, 1935, **29**, 2351 ; W. T. Astbury, *Nature*, 1936, **137**, 803.
[8] W. T. Astbury, and S. Dickinson, *Nature*, 1935, **135**, 95 & 765 ; 1936, **137**, 909 ; " X-Ray Studies of the Molecular Structure of Muscle " (*in prepar tion*) ; " Protein Structure from the Viewpoint of X-Ray Analysis " (*Sörensen Jubilee Volume—in press*).

THE STRUCTURE OF KERATIN FIBRES

To the Editor.

Sir,

So far as the chemistry of keratin fibres is concerned, the letter[1] and a recent article[2] by W. Harrison contain a number of misconceptions which require correction. After reviewing the evidence we have advanced[3] in favour of the view that permanent set is due to the formation of new cross-linkages between the peptide chains by the interaction of basic chains (amino groups) and the products of hydrolysis of the sulphur linkage, Harrison states that this view would be " difficult to contest "[2] were it not that substances having no action on free amino groups and disulphide bonds can prevent permanent set. When first made,[1] this statement was unsupported by experimental evidence and did not merit comment, but in the recent article,[2] examples are given of substances which Harrison regards as preventing permanent set without affecting free amino groups and disulphide bonds. Chief among these is magnesium sulphate: " Thus whilst boiling water will produce permanent set in stretched fibres, the addition of 5 per cent. magnesium sulphate almost entirely prevents it." There is not the slightest foundation for this statement. Human hair fibres immersed at 40 per cent. extension in boiling 5 per cent. magnesium sulphate solution for 30, 60 and 120 minutes, were found to retain 0·5, 8·0 and 14·9 per cent. set, respectively, after release in boiling water for 60 minutes. In this, as in the other relevant cases, Harrison has failed completely to take account of the effect of the *p*H of the setting medium on the rate and extent of setting, although the subject has been fully discussed in a number of papers from this laboratory.[3]

Equally misleading are Harrison's comments on the phenomenon of supercontraction. He seems to have ignored the fundamental fact that the supercontraction to be interpreted is that which occurs when fibres are released in steam after being steamed for 2 minutes at 50 per cent. extension. The changes governing such supercontraction precede the reactions responsible for permanent set, and hydrolysis of main peptide chains is not an essential feature of either. In fact, the very reverse is the case because we have shown[4] that " hydrolysis of the main peptide chains permits their collapse despite the rebuilding of linkages between them." Consequently, in any attempt to elucidate the reactions responsible for the supercontraction which precedes permanent set, attention must be restricted to those reagents and processes which induce supercontraction without causing serious hydrolysis of main peptide chains. With such considerations in mind, we found that disulphide bond breakdown is essential for supercontraction by demonstrating that reagents such as sodium sulphide, potassium cyanide, sodium bisulphite and silver sulphate, which are known to attack the disulphide bond of cystine, cause supercontraction of wool fibres. Of these reagents, sodium sulphide and potassium cyanide might at first sight be regarded as questionable on account of possible main chain hydrolysis ; but the former was used in dilute solution in the cold for 60 minutes, the latter was used in dilute solution at the boil for only 30 minutes, and both were very much more effective in causing supercontraction than corresponding concentrations of caustic alkali under similar conditions. Finally, the list of reagents which attack the cystine linkage and cause supercontraction may be extended almost indefinitely. For example, chlorine peroxide, which is regarded by Schmidt[5] as having no action on the main peptide chains, causes supercontraction by breaking the cystine linkage ; and the combined action of sunlight and air, which has been shown to be restricted to the cystine linkage,[6] promotes supercontraction. Conversely, if a fibre is supercontracted by boiling in 5 per cent. sodium bisulphite solution for 1 hour, and is then washed, stretched and treated with oxidising agents or metal salts to reform linkages between peptide chains, supercontraction is prevented and the fibre acquires a true permanent set. Similarly, the fact that salt linkages oppose supercontraction was proved by showing that borax and

sodium sulphite, which are incapable of causing supercontraction with untreated fibres, cause supercontraction with deaminated fibres. There is thus overwhelming evidence to show that supercontraction is caused by the breakdown of salt and sulphur linkages, leaving the main peptide chains reasonably intact. The only logical way for Harrison to refute this view would be for him to name some reagent which *does* attack the cystine linkage and *does not* assist supercontraction. Instead, he states that " supercontraction is caused by quite a lot of other reagents which have no specific action on disulphide linkages."[2] No example was given in the original letter,[1] and only one example—" a hot concentrated solution of zinc chloride "—is given in the more recent article.[2] Unfortunately, this reagent causes supercontraction simply by hydrolysing the main peptide chains, and observations based on its use have no bearing on the supercontraction which precedes permanent set, because this supercontraction takes place *without* significant main chain hydrolysis.

In conclusion, it should perhaps be mentioned that Harrison's failure to realise supercontraction, when fibres are dried *slowly* after being boiled in sodium bisulphite solution, does not disprove our views on the chemical mechanism of supercontraction. It should have been obvious that the failure was due simply to the fact that disulphide bond rebuilding occurs in the extended fibres by atmospheric oxidation[7] of the abnormally large numbers of sulphydryl groups present in the bisulphite-treated fibres. Surely supercontraction must not be expected when the conditions are such as to impart permanent set!

Textile Chemistry Laboratory,
Leeds University.
November 16th.

J. B. Speakman.
J. L. Stoves.
C. S. Whewell.

REFERENCES

1 Harrison. *J. Text. Inst.*, 1937, **28**, P110.
2 Harrison. *Chemistry and Industry*, 1937, **56**, 731.
3 Speakman. Nature, 1933, **132**, 930; *J. Soc. Dyers and Colourists*, 1936, **52**, 335; 423; *J. Text Inst.*, 1936, **27**, P231. Speakman and Whewell, *J. Soc. Dyers and Colourists*, 1936, **52**, 380. Speakman and Stoves, *J. Soc. Dyers and Colourists*, 1937, **53**, 236.
4 Speakman. *J. Soc. Dyers and Colourists*, 1936, **52**, 337.
5 Schmidt. *Ber.*, 1922, **55**, 1529; 1925, **58**, 1394.
6 Speakman and McMahon. *Trans. Faraday Soc.*, 1937, **33**, 844.
7 Speakman. *J. Soc. Dyers and Colourists*, 1936, **52**, 425.

Reviews

"Textile Design." By Antony Hunt. (No. 15, " How to do it " series). The Studio Publications, 44, Leicester Square, W.C.2. 7s. 6d. net.

The vigorous way the author has expressed his opinion upon this subject is infectious and makes the reader of this book quite enthusiastic about the problem of designing for textiles.

The various sections of the book are well planned and offer good advice in many directions even to the mounting and presentation of designs. Its main aim is, by word and illustrations (34 excellent photographs), to stimulate the artist designer and to help in the appreciation of the qualities of textile materials suited to various uses but especially to " interior decoration " in its most progressive form. This is excellently described and illustrated and should be studied by all who would progress in textile design by experimenting with the newer means of artistic expression now available for this purpose.

Whilst dealing primarily with the æsthetic side of the problem, the technical limitations are also considered with a view to making the individual " cloth conscious."

The book is worthy of better diagrams of printing processes than those on page 54. A more serious effort in this respect would have helped towards a clearer explanation of " Printed Fabrics "—an important element of the work.

According to the cover, the fundamental aim of the book is " To help to bridge the gap existing between designer and industry and to show methods whereby the artist may overcome the many technical problems involved. In this respect it makes great progress in the right direction and contains a wide range of information for all who deal with the problems of textile designing.

P.O'B.

Betriebs und Selbstkostenprobleme der Wollindustrie. von Dr. Ing. Cl. Sustmann (Verlagsbuchhandlung Julius Springer, Berlin W.9, pp. *VIII* and 157. Price 9·60 R.M.).

This very far reaching book covers costing in every process from the spinning of the yarn to the finishing of the piece. The deductions the writer draws, and the conclusions he comes to, are calculated to bridge the gulf between theory and practice. These are derived from the long study of machines and operatives, working under normal conditions in various modern factories, and the figures and statistics collected are most interesting in themselves, apart from their value to the costing plan subsequently developed.

A full set of tables, giving power, lighting, and other overhead costs for each process, as well as the production of every machine under normal conditions is provided. Against these calculated theoretical figures, there are the actual figures obtained under running conditions, a very different matter, as all know, and as the figures clearly demonstrate.

The costing system advocated is the one that almost all cost accountants recommend, the very minute examination of all costs and their allocation to the separate machines, so that each machine, or group of similar machines is rightly assessed and stands its fair share of overheads. This system is too well known to need further explanation. It may quite easily be adapted to any plant with fairly standardised machinery doing a plain trade, and this book will give many valuable hints as to the best procedure to adopt, and the pitfalls to avoid.

It is the method of establishing these costs that is the chief merit of the book. The thoroughness of the tests, and the number of tests taken, make the book a real reference work to the production manager. Whilst everyone knows roughly the variations in efficiency due to varying speeds, materials, and even operatives, there are few who could give actual figures, running into periods of years in some cases, to establish their claims.

Nothing is stated as a fact in the book without figures to prove it. Some of the articles on the various processes will create considerable surprise, when it is seen what a vast difference efficient methods can produce, particularly in the winding and warping. Mere speeding up of machinery as some very interesting tables show, may easily be a double-edged sword, and turn against its holder.

The root principles of efficient production are well known to all. They include good material, long lengths, suitable machinery running at a speed adapted to the material, and, most important, good craftsmanship from the operatives.

The detection of the weak link, however, is not so easy, but a thorough investigation of plant, on the lines of this book, and the systematic keeping of records should effect improvements in many establishments and might even make them approach some of the efficiences he suggests, which seem so far away from reality at first glance.

J.E.

Fundamentals of Textiles. A. Workbook. By Eda A. Jacobsen and Helen E. McCullough. Published by Chapman & Hall Ltd., London. (154 pp., 7s. 6d. net.)

In a review of this volume the following extracts from the preface appear to be vitally necessary. " The purpose of this book is to give those interested in textiles and clothing specific information which will serve as a guide in their buying problems. It provides exercises covering the fundamental material in the field of textiles, from raw materials through construction, identification, analysis, choice, use, and care of fabrics. The emphasis is on the practical and not on the highly technical and specialized phases of the subject." " Since this is a workbook best results will be obtained if the procedure outlined here is observed in using it. The student should read the introduction to a specific unit and study the references which have been assigned. She should then carry out

the directions given for the exercise, answer, either in writing or orally, any questions which the instructor may assign, and be prepared to participate in the class discussion and criticism that follow."

Such a preface disarms criticism in advance. From the third sentence in the second quotation it is assumed that the book is meant for the use of the ladies who are usually considered to form the greater part of the textile purchasing public. A perusal of the volume leaves the impression that the book is intended more as a guide to the teacher than to the student, and that the latter, without the aid of the former, would derive little benefit from a study of the work.

There is no doubt that the user of textiles in the home could derive much information in a pleasantly discursive fashion from a course such as that outlined by the authors. Consequently it is a pity that in a book dealing with fundamentals, fundamentally wrong ideas, such as "elasticity" on p. 48, should be repeated. Even a shallow dipping into the scientific literature of textiles will show that the ready deformability of knitted fabrics must not be termed "elasticity" which has long had a precise scientific meaning. If the work of D.13 Committee of the American Society for Testing Materials can be studied with regard to twist in yarns (see Question 30, p. 25) surely it can be consulted on the exact distinction between "extension" or "elongation" and "elasticity."

Presumably the object of the questions which follow the various "logical blocks" or "units" is to stimulate the interest of the reader or students in as many directions as possible. If this is correct the questions, ranging as they do from simple fibre identification to textile trade unionism, are an unqualified success. A thousand page volume would be insufficient to contain the answers in many cases.

There is no doubt that this work will form a useful practical supplement to the dozen or so volumes on textiles to which the reader is referred. The purchaser who studies the course outlined and uses the knowledge thus acquired should be able to purchase wisely. T.

Toxicity of Industrial Solvents. Summaries of Published Work, compiled by Ethel Browning. Medical Research Council, Industrial Health Research Board. Report No. 80. (Published by H.M. Stationery Office, London. Price 7s. 6d.)

This volume cannot fail to be of the utmost use to all who employ volatile solvents and who are therefore concerned with the effects these substances may have on the health of workers. Attention to the possible dangers connected with the increasing use of volatile solvents in industry is drawn from time to time by fatal accidents and coroners' inquests thereon. The need for research is therefore perfectly clear and the first step in this direction is the collection of the available knowledge and its presentation in convenient form. Dr. Browning's summary, which does not claim to be exhaustive, will aid those who have to direct the research. T.

Kunststoff-Wegweiser durch die Kunststoff Ausstellung, 1937. G. Kränzlein and R. Lepsius. [Berlin ; Verlag Chemie G.m.b.H. ; 1937 ; 140 pages ; R.M. 1-15.]

The special feature of the triennial Chemical Engineering Exhibition in Germany this year was Plastics. The present little book is essentially a guide to the exhibition but contains much information of a more permanent kind, especially an alphabetical list of the trade names of German plastics, their makers and their chemical origins.

Teoria delle Armature Fondamentali per Tessuti. Prof. G. Strobino. [Biella ; Editoriale Laniera S.A. ; 1936 ; 505 pages, 301 illustrations ; 8s. 6d.]

We welcome this Italian contribution to the theory of weave construction with the hope that it may be made accessible to English readers. In spite of the number of pages, it is not really a large book for the margins are extremely generous and the illustrations (drafting plans, etc.) occupy much of the space. It deals comprehensively with the geometry of weaves and is particularly welcome for its indications of other original work in this field.

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXVIII DECEMBER 1937 No. 12

PROCEEDINGS

NOTES AND ANNOUNCEMENTS

Institute's Examinations

The Examinations conducted by the Diplomas Committee in connection with the award of the Associateship Diploma are to be held in May, 1938. The exact dates are:—

Part I, Wednesday, May 18th ;
Part II, Wednesday, May 25th.

Part I will be held in Manchester only, except under special circumstances. Part II will be held in Manchester and such other centres, at home and abroad, as the number of candidates warrants.

Annual Conference, 1938

This event has now definitely taken shape. It is to be held in Scotland and the headquarters chosen is the Hydro, Peebles. The period will be 18th to 25th June and special transport facilities are being arranged. One day of the period will be devoted to a visit by motor coach to the Empire Exhibition in Bellahouston Park, Glasgow. Lunch will be taken in the Exhibition. Mr. J. W. Peck, Secretary to the Committee of Council on Education for Scotland has accepted the Institute's invitation to be principal guest at the Conference banquet. A preliminary announcement with attendance forms will be issued in January and all members are asked to consider very seriously whether they should not make Scotland—and the Institute's Conference—their holiday venue this coming year. Accommodation at the Hotel has been reserved but if not taken up early cannot be guaranteed as " all the world and his wife " are going to the Empire Exhibition in 1938.

Textile Technology, Textbooks and Monographs

At its November meeting Council considered four resolutions from most responsible sources all to the effect that the present position in regard to the availability of up-to-date text books in textile technology is most unsatisfactory. In December further consideration was given to certain definite proposals designed to remedy the unsatisfactory position referred to above. It was agreed that the Institute should undertake the task of preparing suitable pamphlets or monographs at prices well within the reach of students. It was further agreed that the work should be entrusted to an Editorial Board. It is hoped to make a further announcement in this matter early in the New Year.

Annual Meeting, 1938

The President, Mr. John Crompton, at the December meeting of Council urged that the Annual Meeting in 1938 should be held in some town other than Manchester. He suggested that the venue should be Halifax. This received unanimous approval and the date was also fixed for Wednesday, 27th April. It is hoped that a good attendance will be secured, particularly of Yorkshire section members.

TEXTILE INSTITUTE DIPLOMAS

Elections to Associateship have been completed as follows since the appearance of the previous list (September issue of this *Journal*):—

ASSOCIATESHIP

CROPPER, Ernest (Bradford)
DUCKWORTH, Robert Hartley (London)
GOKSON, Allen (Shanghai)
ROSS, W. Heaton (Belfast)
SUGDEN, Ernest H. D. (Leicester)

Employment Register

The following announcements are taken from entries in our Register of members whose services are on offer. Employers may obtain full particulars on application:—

No. 140—Young man, 29 years of age, desires position as Manager in Woollen Mill, able to take full control. At present employed by firm making all types of Fancy Woollen Cloths—worsted warp/woollen weft, cotton warp/woollen weft, suitings, overcoatings, ladies' dress and coating, etc. Conversant with designing and all processes from raw material to finished cloth, and with customers' requirements. Holder of City and Guild Certs. and Diplomas. Excellent references. Experienced in handling workpeople.

No. 172—A.T.I. requires Managerial or Executive position. Full Tech. Cert. in Manufacture of Hosiery and Knitted Goods. 4 years' apprenticeship with Knitting firm, 1 year Nottingham University. Knowledge of costing, labour control and modern knitting machinery.

No. 174—Desires position of responsibility, preferably in India. Practical experience in erection of machines. 1st Class Diploma of City and Guilds of London Institute in Plain Weaving (Final). Full Technological Diploma of Bolton Technical College.

No. 175—Applicant desires position as Head Carder at a large Mill or inside Manager. Full Technological Certificate. 2nd Prize for Bolton Master Spinners on Cardroom processes. A.T.I. 5 years' experience as Head Carder. Age 34 years.

No. 176—Young man, 28 years of age, desires position as Manufacturers' City or London Representative, City and Guilds Cert. in Textiles and Distribution. Chamber of Commerce Certificate in Silk and Rayon. Ten years' experience in furnishing fabrics.

Institute Membership

At the December meeting of Council, the following were elected to Membership of the Institute:—

Ordinary

J. Atack, 66, St. James's Road, Carlisle, Cumberland (Sales Manager, Robert R. Buck & Sons Ltd., Carlisle).
B. Flitcroft, Peru (Weaving Master).
H. H. Gauntlett, "Selborne," Harrow Road, Wembley (Drapery Salesman).
E. W. Goodale, Warner & Sons Ltd., 10, Newgate Street, London, E.C.1 (Managing Director).
F. O. Howitt, M.Sc., Ph.D. (Lond.), F.I.C., 1, Vaudrey Drive, Cheadle Hulme, Cheshire (Head of Silk Section, British Cotton Industry Research Association, Didsbury, Manchester).
C. Whatmough, 2, Hilltop Avenue, Cheadle Hulme, Stockport, Cheshire.
H. Wood, 8, Stonegate Farm Road, Meanwood, Leeds, 7 (Cloth Finishing Instructor, The University, Leeds).
J. F. Wood, B.Sc. Eng. (London), 51, Melrose Avenue, Bolton (Technical Assistant, Musgrave Spinning Co. Ltd.).
R. Wood, Arran Garth, Moorville Drive, Birkenshaw, nr. Bradford (Colour Matcher, Worsted Spinners).

Junior

H. A. Griffiths, 46, Glenhaven Avenue, Urmston, Manchester (Student).
P. B. Law, 9, Garden Lane, Heaton, Bradford, Yorks. (Textile Chemist).
A. Toft, 35, Wetherby Street, Higher Openshaw, Manchester, 11 (Cloth Salesman).

Lancashire Section

SOME ASPECTS OF THE RELATIONSHIP OF ART TO INDUSTRY

A Lecture delivered to the Lancashire Section of the Textile Industry on Saturday, 9th October, 1937, by W. Turnbull, Esq., J.P.

Mr. Turnbull said: It is not my intention, nor have I the knowledge to deal with the question of Industrial Art in its wider sense, and I shall therefore confine myself to those aspects of the subject with which my daily work brings me in contact, and so I speak as a young calico printer to young designers. If in doing so I appear to be dogmatic, will you please take it that every such statement should be prefaced by " it seems to me "!

It will offer a good starting point if we consider for a moment how the calico printing trade supplies itself with designs and (what is of equal importance) colourings, these being what it lives on. I say of equal importance for I am certain that many a poor design has achieved success through good colour, just as many good designs have been rendered useless by bad colouring. Well, your calico printer sells printing, sometimes he buys cloth and sells cloth and printing, and the great bulk is sold to merchants who sell to other merchants who sell to the retailers who sell to the public. Often the merchant supplies the design; sometimes the printer gets designs from free lance designers, commercial studios or, if he has one, from his own studio. If it is the dress trade it is fairly certain that the source of the inspiration is French. Shirtings are almost certain to be English. Furnishing fabrics, cretonnes, etc., are generally English though Continental studios have easy entry into England; and one finds French, German and occasionally Austrian designers showing their rolls in considerable numbers.

Whatever the sources of the designs, they require engraving or cutting or screen making. Some of the larger firms do this important work themselves—for those who don't, there are the " jobbing " engravers, etc., who do it for them. Whoever does it, it is costly and skilful, requiring co-operation between printer and engraver. Often the " designs " are just sketches or " croquis " and need licking into shape as regards correct repeat, etc. Etches and strengths of engraving also need discussion. Sometimes the " croquis " are turned into the printer's studio, sometimes into the engraver's.

When the rollers reach the printer, sampling has to be done—if a multi-coloured design, preliminary colour sketches are done in the studio, whose head, acting in collaboration with the manager or art director, is responsible. These sketches are submitted to the merchants and are sometimes accepted by them in lieu of striking off the colourings on cloth. Whatever the method adopted, speed is increasingly a *sine quâ non*. The merchant is driven for delivery dates and he drives everyone else. Often he wants designs or sketches to a particular idea to clinch an order—and he wants it the next day! It is a sign of the times and reflects the increasing attention being given to design and colouring that in some cases the merchants are employing a designer themselves as a whole time job. An excellent move this, and one which should help them to be considerate to the efforts of others.

Multi-coloured cretonnes, linens and chintzes require careful sampling, and inquests on them are usual. Where the designer is directly employed by the printer, he is called in, though his views generally get short shrift if they are in opposition to the art director's or, more generally, the sales manager's, who naturally feels he knows what is required. Sometimes indeed he knows himself to be a better colourist than the designer—not every designer is a colourist.

Now if the printer is selling printing (or cloth and printing) to a distributor on commission, he has to submit his results to him to get his order and again there is an inquest. When the printer merchants the goods himself he usually

submits his trials to his London House which, in its turn, makes its comments. Having finally got everyone's ideas co-related, he proceeds to print stock. In the case of a furnishing fabric he finds that he has spent on design, engraving, sampling and stock between £500 and £1,000. If he has got a winner—well and good—if not, he obviously stands to lose heavily. It is easy to appreciate therefore why he plays for safety and is conservative!

The technical and scientific sides of the printer's job are involved and by no means automatic. Even when the pattern is set up in the machine, it requires all the printer's attention to keep it in fit. In his processes the cloth veritably passes though ordeals of fire and water. He must know how to deal with myriads of colours involving curious chemical changes, and he must do all this at a price and under merchanting conditions often little short of degrading. Let that be as it will, I claim for the calico printers of this country that they are second to none in the technical excellence and craftsmanship of their products! Of course, I do not claim that all their lines are equally worthy, but neither are those of the foreigners. Whether their "artistic" quality is equal to their "technical" merit is the subject of much heartburning. One thing is certain—there is always room for improvement and I take it that the *raison-d'être* of this Institute and its examinations and competitions is to help towards this goal.

From the designer's point of view the subject may be treated under four heads—Works Studios, English Outside Studios, Continental Studios or Ateliers, and Free Lance Designers.

Works Studios.

Designers employed by works sub-divide themselves into those doing more or less original work, and draughtsmen or women who are altering croquis to meet technical requirements, doing colour sketches and filling in their spare time with work of more or less original character. The head of the studio is a competent designer, capable of original work but who can direct others, and possesses a cultivated judgment. In some cases, such as the firm I represent, there is an artist who is kept away from the industry; from him we expect and get work of the highest artistic excellence, generally (but not always) of technical accuracy and a little ahead of the feeling of the moment. In addition, we have a designer of ordinary studio capacity working in our London sales-room doing original work and also colour sketches or altering those sent from the works.

It would appear that there is too much sub-division, but it is a mistake and one often made, not to recognise that in matters artistic as in most others, there are "hewers of wood and drawers of water". My own experience is that this type of organisation fulfils its purpose of keeping the standard of work at once high artistically and yet practical technically. At the same time, your artist *qua* artist is better working away from the plant if he is to keep his ideas fresh, and he ought to be in a position to shove his head in the clouds occasionally. His occasional visits to the plant are good for him and refreshing for us!

English Outside Studios.

I have little first-hand knowledge of the inside of English studios, or less of Continental ones. I gather from my talks with some of the heads of these studios that there are much the same sub-divisions though probably not to the same extent as in the works studios—it is probable that the technical knowledge of the draughtsmen whilst adequate, is not too precise nor is it to be expected. In my experience with the work of the Manchester studios, what astonishes me most is the speed and accuracy with which they fulfil their rush jobs.

In dealing with the outside studios we ought not to overlook the engravers' studios—not all engravers have them, but there can be little doubt that for precision in such styles as trouserings, shirtings, etc., they are wonderful. I presume that in the extremely fine effects such as mottles, hair line

stripes, etc., they can avail themselves of existing dies. It is inevitable that this precision is sometimes offset by a too mechanical feeling in their work. Nevertheless their value to the trade is great. They are also past masters at turning a croquis into a working drawing and at taking out the unforeseen " strikes " in other designers' work—long may they flourish!

I am more at home with the products of the London studios working in the main for the furnishing section of the trade. It is not surprising that each studio develops and maintains its own handwriting—it is quite easy to recognise their work even though the designs be by many individual workers. Is this a good thing, I wonder? If it is *not*, is it inevitable? Within my own experience it sometimes results in one studio having a lean time whilst another is booming. Perhaps what they lose one year they gain the next—I don't know. Anyway, there can be no doubt of their ability in their own line. It will be realised that they have the advantage of the views which the head of the studio picks up in his interviews with the trade buyers. Not only so, but they have the Museums and Art Galleries at their door, not to mention the Exhibitions and the shops.

Continental Studios.

I should not be surprised if the very mention of these sends a shudder down the backs of designers present. Why, you may ask, does the Government allow them to bring their wares in free and so take the bread out of our mouths? But does it work quite this way? Is it not rather a fact that the French still take the lead, and deservedly so, in the dress trade? Whilst I am not primarily interested in this trade, those who are tell me that this is perfectly true. And is it not also a fact that without accusing the trade of plagiarism in its grosser manifestations, it yet picks the brains of the Frenchman (the German and the Austrian, too, for that matter). But as I hope not to be contentious, let us leave this aspect of the situation and look at it from another point of view. It is asserted very confidently in artistic circles that the Frenchman knows this trade inside out, that he has a flair for it and that he designs with due regard to the purpose, the material and the process—in a word, that his designs are the best in the world. Now if, as I contend, there are no better printers in the world than the English, and if the English buy French designs—the best in the world—the result should be that English dress goods are unequalled. Yet we are constantly told that this is far from being the case. Are we then driven to this conclusion—that the English buyers of French designs do not indeed buy the best of what the Frenchman offers? I do not express an opinion, but leave it with you. In arriving at your own conclusion, you ought I think to consider the psychological aspect of the question. For instance, Englishmen are not interested in the dress of their ladies—Frenchmen are. Again, Frenchwomen desire above all things to wear exclusive designs. I am far from being critical when I say that Englishwomen are only interested in exclusive designs after they have seen someone else wearing them and so feel they are in the fashion and not ahead of it.

As to the Continental furnishing designers, with one or two exceptions, I confidently place them below the English studios so far as prints are concerned, though there can be little doubt that they have been far ahead of the English studios in their presentation of woven designs. Their surprising ability to indicate in realistic fashion the incidence of the play of warp and weft has to be seen to be believed—and when, added to this, they supply you with a cutting of a previously woven fabric showing similar effects, it will be realised that they have been extremely thorough. On more than one occasion, I have found my firm's best sellers attached in this way to a design in a Frenchman's collection—I was torn between admiration for his perspicacity in recognising a good thing when he saw it, and annoyance that he should be offering me and my competitors a poor substitute for really good English work! On the whole, I think I felt flattered and did not even point out to him that he had committed

a " faux pas "! After all, as my grandfather used to say, you " cannot turn the mill with the water that is passed ", and so long as we have a lead, others are welcome to follow!

But, to return to the French studio in relation to decorative fabrics, in one respect only do I think they are ahead of the English and that is in showmanship. For instance, they are neither diffident nor aggressive. Their quiet efficiency in displaying their wares is in sharp contrast to the fumbling, knot-untying Englishman. Their designs are generally clean, with exactly the right amount of plain border for the amount of work. Nor do they fall into the error of so many young English designers of decrying their own goods. Let me add, though, that in general the designs themselves will not stand comparison with their English prototypes. For instance, they almost invariably adopt a drop repeat for a 30″ cretonne—it achieves balance and entails the minimum of work. Most English designers design for the whole 30″ width—a more difficult and tedious job, but infinitely more interesting. To my mind also they fall into two errors at either end of the scale—either they spoil their small designs through saving on the number of colours, or alternately, in their large designs they put far too many in. You will, I hope, take these remarks in their general sense, because there are notable exceptions.

Free Lance Design.

These designers are at once the hope and the despair of the printers. I noticed in one of my father's articles that he referred to them as the " unpaid research workers of the trade " in relation to design. Well, there is an obvious reason why this must be so. These unattached designers plough their lonely furrow. They have the great advantage of freedom from industry and are untrammelled by technical restrictions. Apart from the economic pressure of having to make a living, they can do exactly what they like when they like. The result is, sometimes, designs of a surprising freshness of outlook, though too often mixed with a preponderance of pot boilers. Few there are who can maintain their position of independence without some extraneous help, and many of the best have found their way out by joining the teaching profession or by writing a book, or both. It is a risky job and ought not to be lightly entered upon by the very young. If indeed you must do it, then try to find a partner who designs for some other branch of the trade. Pool your resources and your expenses—it will, at least, give you both the advantage of discussion and mutual assistance.

As to the Continental free lances I have had experience of only three, and they have all been good. Incidentally, they were all attached to schools and were interested more in " Kunstlerstoffe " than commercial propositions and they all faded out of our ken in a short time. Perhaps the economic pressure, or it may have been political pressure, operated to keep them in (or out of) England as the case may be.

I have not, so far, attempted to do more than describe the position of the designer and the calico printer in relation to each other, as I know it in practice. It would be pertinent to enquire into the results of their curious and somewhat haphazard co-operation. I do not intend to say very much about this aspect of it. Admittedly, our shops bear evidence of much that is commonplace and even tawdry; more that would be good, but for the too obvious signs of the derivative nature of the designs, and quite a respectable amount of really good fabrics. In addition there are always the novelties so frowned on, by the serious, and loved by the cheerful. I class myself amongst the latter—surely a little folly may be excused if it has the saving grace of humour and entertainment! This is by the way. Now I have in my short life had the pleasure of repeated visits to the Continent and to America, and it is my considered view that, if you compare like with like, this country produces by far and away the best printed fabrics. Sweden produces more interesting handwoven fabrics, and French silks and dress fabrics are unsurpassed. For economical

judicious use of vat colours, the German can teach us much. It may even be that U.S.A. has travelled much farther than some of us in the development of screen printing. In spite of all this, the time has gone by when England's participation in an international exhibition of printed goods, would do anything but add lustre to the rest; always please note if you compare like with like.

But lest we get too conceited, let me add that much of the products of the world's printing machines has nothing to do with Art. I hold no brief for it, but it is there—let us class all such rubbish amongst the things made for sale and not for use. It is not confined to our trade nor to our country, and its elimination lies in economics rather than in aesthetics.

I am not " au fait " at first hand with the efforts being made on all sides during this post-war period to improve the education of all concerned in the production of things in which good design is or should be a constituent. I do know that much effort and thought has been, and is being, put into this side of the question—indeed I am optimistic enough (or should I say young enough) to think there are already signs of results from these efforts.

To young designers I should be the last person in the world to preach. I have a very fellow-feeling with them as I realise their very great difficulties. On the one hand there is the difficulty of getting to know the legitimate demands of industry, and on the other, there is your keen desire to be allowed to express yourself in your own way. It is so terribly easy to let all one's ideals go. It is easier still to blame industry for it when it happens. But to those who make a fight for it, I would ask them to make up their minds as to what are the legitimate demands of industry, and to work to them. After all, one should not overlook the fact that criticisms come in many cases from well-informed people who have spent a lifetime at their jobs and are by no means uninstructed in the designer's art. May I just mention a few points of this kind?

(1) If in designing a 50″ wide cretonne you do the obvious thing of putting your main motif bang in the centre of the cloth, you will very likely be told that this is wrong and that the pattern should have two centres, one in each half width, side by side. In other words, that your design should be 25″ wide by 18″ high and repeated side by side. The reason is that as 70 per cent. of cretonnes on a good cloth are used for loose covers, and as the 50″ full width will cover a settee and the half width will cover an arm chair, it is necessary to have a centre for each—the settee having two, will at all events balance.

(2) If you design for a 30″ cretonne intended for curtains, etc., and you so design it that it can only be used by cutting a lot of cloth to waste, it is a legitimate criticism to say so and to ask you to scheme things so that this waste will not occur.

(3) If your design involves the use of animals or figures, and you so design it that it has to be joined through these motifs in making up, you may legitimately be told that this should be avoided at all costs—it is impossible to join figures without distortion.

(4) If you are designing for reversible cretonnes and you use more than six colours you should thank your stars that someone goes to the trouble of pointing this out to you.

(5) If you have managed to get adventitious " strikes " in your design, in spite of your efforts to avoid it, you may well find some buyer who notes it immediately—just thank him if he points it out.

The great thing to remember is that if he shows the slightest interest in it, it is because there is about it something which attracts him. If you can get him to talk, listen intently.

As to the illegitimate demands of the trade, they are not so easy to define. Those which occur to me are all bound up with the appropriation of ideas to which unfortunately some designers, no less than some buyers, are prone.

Illicit copying is a slippery slope. But I have no doubt that all my young friends here will see to it that they do not place themselves on it. All our strivings for something better, all our efforts at self expression are worth nothing unless we see to it that they have their bases in common honesty. Honesty is not too common, and people who would disdain to pick your pocket, think it no crime to steal your ideas!

It was suggested to me that I should deal more particularly with the question of colour. It is quite outside the scope of my theme, nor am I competent to deal with colour in its scientific or chemical aspect. Nor do I consider it as so directly important to the designer—it is rather a matter for the chemist in conjunction with the art director. I might say though that in my opinion we in England have not been so logical as the Germans as regards designing for the proper use of vat colours. These colours are very costly and in this country they have been splashed about regardless of cost. For instance, we have not reduced the number of colours in our designs, and also we have actually based our colourings on the series which has meant giving a depth of shade without reference to the excessive cost. The German, on the other hand, has strictly limited both the number of colours in his designs for this series and also has adopted pastel-like shades, thereby effecting due collaboration between works and studio. But these are matters for the printer and his art director, as also the type of designs and colours for the naphthol series of colours.

In its aesthetic sense I find it difficult to discuss this colour question in relation to design. The trouble is that there are few criteria, except one's own feeling and personal reaction. Nevertheless, there are one or two things which a designer (particularly for multi-coloured designs) ought to have in mind. First, it is important that the colour scheme he adopts for his original design should be such as will not mislead the printer or his colourist when he comes to do alternate schemes. In other words, the original colour scheme should be a map which will pan out right when other colours are used in the same relative strengths.

Secondly, is it too much to hope that designers will not always stick so closely to the traditional type of colouring even for traditional designs? Every design seems to have the same pink, red, yellow, blue, green and black and the same old quantities and in relatively the same old positions. Why not be more adventuresome occasionally? You may say that other colourings are used, but I think it is true to say that these are usually the product of the works studios. I mean, for instance, the browns, russets, oranges, lime greens, sage greens and soft yellows, or again the blues, greys, the soft mauves and yellows, etc., etc. Young designers might well make a study of these types of colour schemes with advantage to themselves and all concerned.

When all is said and done imaginative form and sound drawing ought not to be constantly allied to a stereotyped colour scheme. If for no better reason "many a poor design has been made (and sold) by good colouring."

Just one word in a general sense—it would be interesting to know how artists begin their designs. Do they imagine them whole and complete before they begin, or do they sit at their easels and let the design flow from their finger tips like spirit writing? These are interesting speculations for a layman, but one thing I do know—I have seen many designs evolved from images created by a word, a phrase or a name. For instance, one of my sisters produced a real winner based on the phrase "industrial revolution." Other ideas which led to fruition were the "Dutch Bouquet", "the Chinese Landscape", "the Pleiades", "Sea-foam", "Alternating", "Golden Triangles", etc., etc. My point is that these were christened before they were born. May I suggest that this is an idea worth pursuing? One could think of a hundred titles from one's daily round, the streets, the theatres and the cinemas.. I leave it with you to think over.

The Lancashire Section of the Textile Institute met at the Municipal Technical College, Bolton, on November 24th. Mr. Thomas Dutton, F.T.I., presided and there was an extremely good attendance. In the unavoidable absence on the Continent of Mr. H. Hill, of Messrs. Howard & Bullough Ltd., his paper on " Recent Developments in Cotton and Staple Rayon Spinning Machinery " was ably read by his colleague Mr. Hunter. The lecture was copiously illustrated with slides. The paper provoked an interesting discussion which most of the questions dealt with the manipulation of " Fibro " artificial silk fibre.

A vote of thanks to the lecturer was proposed by Mr. F. P. Slater and seconded by Mr. B. Hesketh. Votes of thanks were also accorded to the Chairman and to the municipal authorities for the use of the lecture room.

Mr. Hill's lecture was printed with illustrations by Messrs. Howard and Bullough and distributed to those present.

Mechanical Irregularities and their Effect in Fabric Processing

Abstract of a lecture by Mr. E. Farrell, M.I.Mech.E., on Thursday, December 9th, to the Lancashire Section of the Textile Institute and the Manchester College of Technology Textile Society, at the College of Technology, Mr. W. A. Hanton, M.Sc.Tech., in the Chair.

Dealing with mechanical irregularities due to wear and tear, the lecturer said that they gave rise to very troublesome difficulties in finishing, such as weft distortion, warp extension, and bad stentering resulting in the damaging and " dog-legging " of selvedges. Examining some 20 or 30 machines for scouring cloth in rope form he invariably found grooving of the wooden rollers in the liquor box, the depths of the grooves increasing towards the ends of the rollers. This gave rise to differential slip between the cloth and the roller. Coupled with the roughness which soon develops on the best wooden rollers and the mode of contact between cloth rope and roller, this causes weft distortion. He therefore designed a roller covered with vulcanite and running in ball bearings which was successful in avoiding some of these defects. If greater attention were paid to preventing the occurrence of faults, it would not be neccesary to spend large sums on machines for such processes as pre-shrinking of cloth in order to avoid further shrinkage of garments made from it in the laundering processes. In somewhat similar fashion the wood lag wince, when speeded up in order to convey the cloth from one machine to another, can cause a good deal of weft distortion.

The weft straightener fixed at the delivery end of the stenter operated by accelerating or retarding the stenter clips. Its action invariably resulted in the weft becoming bowed rather than straight if the weft were behind. With leading weft the retardation of the clips gave approximately straight weft. Apparatus for correcting distorted weft before the cloth entered the stenter clips was now available, and constituted a far better arrangement than the older method of straightening weft while the cloth was under tension.

Dealing with " dog-legged " selvedges the lecturer, by means of a drawing, showed selvedge deformation to be due sometimes to tongues or grippers not being parallel to the line of connecting pins.

A very lively discussion followed and Mr. Farrell answered many questions put to him. He said he would like the opportunity to demonstrate his points on an actual stenter, showing how faults can arise and how they can be avoided as well as how they can be corrected.

Professor Morton of the College of Technology proposed a vote of thanks to Mr. Farrell. This was duly seconded by Mr. Barnes, Chairman of the Lancashire Section of the Textile Institute.

Reviews

Collins Textile Diary. Collins Clear-Type Press, London and Glasgow. 2/- net.

Messrs. Collins have added to their remarkable series of diaries a finely-produced pocket book containing information of considerable value and use to those engaged in the textile industry. The compiler has an unenviable task. Even with the help, which is not small, of good quality opaque thin paper and small clear type, the difficulties of deciding what must be included and yet keeping the size of the book within the necessary limits, are very great. Every user naturally desires to use the particular things in which he is most interested given special prominence. The balance between the many interests has been cleverly maintained and no branch of this extensive and many sided industry has been seriously neglected because of undue importance being attached to any particular section.

One superb opportunity has been missed. Page 45 devoted to a table dealing with twist in yarns could well have been sufficiently compressed to make room for the brilliantly clever designation of twist that has emanated from the States and has been sponsored by the American Society for Testing Materials. If the " S " and " Z " description does not ultimately supplant all others it will provide a wonderful example of the difficulty of changing customs hallowed by long usage. T.

Textile Testing. By James Lomax, F.I.C. (Longmans, Green & Co., London, New York, Toronto, pp. viii + 168. 7/6 net.)

Although the application of science to the textile industry is still increasing, the rate of increase is such that the appearance of a new book on textile testing is a matter of considerable importance. The industry covers a wide field, and the man who would be expert and authoritative in dealing with the wide variety of materials in the several branches of the trade would possess a very extensive knowledge indeed. He would have to be at once a mathematician or mathematical physicist, in order to deal with the interpretation of the mechanical and physical tests on raw materials and manufactured goods of high intrinsic variability, and a chemist with a profound knowledge of materials possessing extraordinarily complex structures. It is not suggested, for a moment, that the author has set himself up as such an authority. In fact, his preface clearly and succintly states that he deals with the elements of the subject in the hope that his book might be a useful guide to students, factory testers and others. Since some of the students of to-day may be the important figures in the industry of the future, it is of vital importance that works intended to assist them should be, as far as possible, beyond criticism.

The book that is beyond criticism has yet to be produced, and Mr. Lomax's book is welcome for several reasons. The parts that are good and sound will achieve the object he had in writing the book, and the work is such that the student may be encouraged to delve more deeply into the subject and study the original papers in the Literature. In another respect the appearance of the book is timely. The Textile Institute Standardisation Scheme, in which the foremost plank is the Unification of Testing Methods, has drawn to the whole subject of textile testing a considerable amount of attention. Mr. Lomax's book does the same thing, and since it thus hastens the day when testing will be far more widely applied, it serves a very useful purpose because it will convince some of its readers of the need for testing.

A reviewer must be pardoned if his criticism is confined mainly to the sections dealing with the materials with which he is most familiar. The photomicrographs (why does the author describe his pictures as " microphotographs " when the more correct term has been in use so long?) in section I are very good, though some of them might be accompanied by qualifying references. For example, Fig. 12, the cross-section of acetate rayon, is undoubtedly what is most generally found, and is what the manufacturer is endeavouring to get. But the many hundreds of cross-sections cut by the reviewer have shown every conceivable gradation between the forms shown in Fig. 12, and the " flat " dumb-bell type of which examples can be seen in

Fig. 13, which represents nitrocellulose rayon. " Flat " filaments of acetate rayon have given rise to so many fault in cloth that manufacturers have introduced modifications of spinning machinery in order to obtain some measure of control over the type of cross-section of filament produced.

The author's statement of p. 6 that the dulling of acetate rayon by means of boiling soap solutions is permanent is not correct. The lustre can be restored by appropriate treatment with acetic acid in an easily controllable fashion. It can also be restored by means of a hot iron and moisture, which goes a long way towards proving that the dulling process is a partial dispersion of the colloid rather than a simple conversion of the outer layers of the filaments to hydrated cellulose. A photomicrograph of acetate dulled by boiling in soap solution is instructive. Unfortunately it is not easy to obtain.

The best test in the world even if conducted by the most capable scientist will fail to give a true result for the consignment if the sampling is faulty. With materials of such high variability as textiles this point could well have been more heavily stressed. Dismissal in a couple of pages might leave the impression that truly representative results are more easily obtained than is actually the case. Nothing would have been lost and the importance of the sampling question would have been emphasized if a brief description of the sampling of bales of wool, tops, consignments of yarn, etc., had been given. This leads naturally to the statistical treatment of the results of tests. It is impossible not to feel that Mr. Lomax's treatment could easily have been improved by a perusal of the pamphlet published by the Shirley Institute in 1929, in which the particular needs of textile testing are adequately borne in mind. The loose arithmetical expressions on p. 92 are, to say the least, a poor example to students.

Mr. Lomax wisely advocates the replacement of the present confusion regarding twist nomenclature by the " S & Z " system which appears in the publications of the American Society for Testing Materials. Custom will undoubtedly die hard, as usual, but twist descriptions cannot be standardised too soon. " The sacred permanence of the printed word," to which Professor A. N. Whitehead refers in one of his books, may account for the frequent utilization of matter from older textbooks. Much of this has been proved to be wrong by the research work which has gone on since about 1920.

The book would have been improved, especially from the point of view of the student, by more copious references, and these would be more useful if they were collected at the ends of the various sections. Uniformity in the abbreviations of the names of Journals is desirable, and is not difficult to achieve. On p. 101 the Empire Board Publication No. 21 (" Wool, a Study of the Fibre ") has been attributed both to S. G. Barker and to A. F. Barker, which is all the more remarkable when the name of one of the gentlemen who read the manuscript is noted.

A final criticism deals with illustrations. Half-tone blocks cost more than blocks made from line drawings and frequently are far less instructive. As an example, the picture of the fibre comparator on p. 105 may be noted. A line drawing of the optical system of the instrument could easily have been substituted for a picture which conveys nothing. The explanation may lie in the saving which the publisher can effect by borrowing blocks from instrument makers, but the practice is still regrettable.

Mr. Lomax's task has been far from easy. When the call for a new edition comes, he will be able to rectify the shortcomings of the book. They have been dealt with in a manner which might appear somewhat drastic, but it is hoped that the criticism is constructive in every case. At the same time, it is felt that the book will prove of considerable use to many, and it is hoped that it will soon run to a second edition.

Industrial Fibres, 1937. Issued for the Imperial Economic Committee by H.M. Stationery Office. (Price 2s. 6d. net.)

The statistical data compiled in the Intelligence Branch of the Imperial Economic Committee show how the more important textiles have contributed to the trade revival of the immediate past. For the 1936-1937 season the production and consumption of cotton have broken all previous records. Wool production was the highest since 1929-30 and the clip was well absorbed by the markets of

the world. Rayon continues its expansion. World production of continuous filament yarn in 1936 was nearly 20 per cent. higher than in 1935 and the most notable feature was the advance of Japan to the position of largest producer. For the production of rayon staple fibre the statistics available are not so reliable. In Italy and in Germany phenomenal increases in production were recorded. World production of rayon (continuous filament and staple fibre) was about 1,300 millions of pounds in 1936 whilst cotton approached 18,000 millions of pounds. The British Empire is responsible for about 10-12 per cent. of the world's production of rayon, for nearly 20 per cent. of the world's cotton and for approximately 40 per cent. of the world's wool.

A study of the figures provided undoubtedly stimulates speculation on the trends in certain branches of the textile industry. A good example is provided by the import and export figures for wool for Japan, Italy and Germany, and their comparison with the corresponding figures for previous years. In these countries it would appear that the production and the use of rayon is likely to cause a considerable reduction in the consumption of natural fibres, whilst in this country and in the United States of America, rayon production is exerting a far smaller influence. It is as yet impossible to draw general conclusions and it would appear that rayon production must expand many times before any appreciable effect on the production of natural fibres can be felt.

It is impossible to overestimate the importance of publications of this character. The form in which the data is presented leaves nothing to be desired.

T.

Practical Loom Fixing. (Fourth Edition). By Thomas Nelson, Dean of Textile School, North Carolina State College of Agriculture and Engineering of the University of North Carolina, Raleigh, N.C. (Published by the Author.)

This useful handbook, as its title implies, is written for the guidance of loom fixers, or as they are called in this country, overlookers or tacklers. It deals, accordingly, mainly with the setting and timing of loom parts and with the causes of and remedies for faulty working of the loom. In addition, however, simple explanations are given of the working of the principal parts of the loom and reasons, wherever possible, for the loom construction described and the settings advocated.

The descriptions are simple and clearly written and are illustrated satisfactorily by easily understood line sketches.

A common fault of books of this type is that they deal in detail with only one or two particular makes of loom and are consequently of very limited interest. This fault has been avoided by the author, for whilst some of the best known American loom mechanisms, such as the Crompton & Knowles box motions are considered in detail in separate chapters, the bulk of the book deals with mechanisms common to different makes of loom.

The chapters on automatic looms of the ordinary bobbin changing and shuttle changing type are short and somewhat inadequate, which is rather surprising considering the wide use of the looms in the United States. On the other hand an interesting and full description, together with notes on its adjustment, is given of the new Crompton & Knowles super silk and rayon loom, which is of the non-stop shuttle changing type. There are also useful chapters on rayon preparation and weaving and on the simple calculations on yarns, cloths, healds and reeds which come within the scope of the overlooker's work.

The book is provided with a good index, but an unusual omission is a table of Chapters and their contents.

An interesting feature of the book from the point of view of the English reader, is the comparison it enables him to make between practice in weaving in this country and in the United States. In some respects the differences in practice may lead to some difficulty. For example, looms in America run in the opposite direction to those of English make, so that timings given for the American looms require to be adjusted accordingly. Again some mechanisms common to this country, such as the cone overpick motion, are not mentioned at all, picking being almost invariably done by underpick on American looms. A statement made by the author when dealing with the underpick motion shows the danger of being too dogmatic about loom mechanism. Referring to the

parallel motion used on American underpick looms to give horizontal movement to the picker he says " Without a parallel motion it would be impossible to run a loom because it is absolutely necessary to have the picker travel straight in the shuttle box. If the picker had to make an arc of a circle . . . . , the shuttle could not be driven across the (s)lay." This is true if the picker is fixed to the picking stick, but most English built underpick looms have the picker loose and have no parallel motion.

The author is on doubtful ground in his chapter on beating-up when he attributes eccentricity in slay movement to the relative positions of sword pin and crankshaft, ignoring the much greater effect of the relative lengths of crank and connecting arm.

In general, however, the author, if he does not go deeply into theory, is reliable, and not only overlookers, but all concerned with the working of looms, will find much of interest in this book. W.A.H.

Symposium on Wear of Metals. Held at a meeting sponsored by the American Society for Testing Materials (Philadelphia District Committee). (Published by the American Society for Testing Materials, 260 S. Broad Street, Philadelphia. Price $1.25.)

The report of this symposium contains 6 papers, one of which, by A. Palmer, Crompton & Knowles Loom Works, Worcester, Mass., is entitled " Wear of Metals in the Textile Industry."

Justice to Japan. By A. F. Barker. (Published by Jowett & Sowry Ltd., Leeds., pp. xvi + 184.)

Additions to the Library

Skinner's Cotton Trade Directory of the World, 1937-1938. Published by Thomas Skinner & Co. (Publishers) Ltd., Manchester. Price 20s. net.

According to the Preface the Hosiery and Knit Goods Manufacturers Section has been completely revised and extended.

Rayon and Silk Directory, 1937-1938. Published by the Harlequin Press Co. Ltd., Manchester. Price 21s. net.

Following closely the form of the previous issue of this valuable work of reference the new volume has increased its contents by approximately 10 per cent. New appendices giving Producers of Bleached Pulp and Rayon and Silk Production, Consumption, Imports and Exports have been added.

The British Launderers' Year Book, 1937-1938. Published by the Institution of British Launderers Ltd., London.

In the introduction to this volume attention is called to some new features. Details are given of the new Trade Order which came into operation on September 13th, 1937. The volume also contains the first published list of members of the Junior Section of the Institution of British Launderers which dates from January 1st, 1937. An appeal is made to Senior Members to help forward this new development.

Catalogues Received

The Lovibond Comparator. (The Tintometer Ltd., The Colour Laboratory, Milford, Salisbury.)

This catalogue gives the applications of the Lovibond Comparator to the determination of pH values for soils and solutions, phosphates, chlorine in swimming pools and many other purposes. It should find a place in every chemical, bacteriological and food and drugs laboratory.

General Items

BRITISH MANAGEMENT COUNCIL.

The Advisory Committee on Management appointed by the Governing Body of the International Labour Office, decided, in 1936, to take up again certain aspects of the work of the former International Management Institute and its second session was held on the 28th and 29th May, 1937. The International Committee of Scientific Management has requested the British

Management Council to give publicity to definitions adopted by the Advisory Committee at its second meeting, Geneva, 28th and 29th May, 1937.

It is felt that these definitions will help to remove the somewhat widespread confusion as to what Scientific Management really means.

I—MANAGEMENT, SCIENTIFIC MANAGEMENT.

(*a*) " Management " is the complex of the continuous co-ordinated activities by means of which any undertaking or any administrative or other service, public or private, is conducted.

(*b*) " Scientific Management " is management based on principles and methods that are the outcome of scientific research.

II—ORGANISATION. " Organisation scientifique (du Travail)."

(*a*) Organisation is the complex of activities the object of which is to achieve the optimum co-ordination of the functions of any undertaking, or any administrative or other service, public or private.

(*b*) " Organisation scientifique," is organisation based on principles and methods that are the outcome of scientific research.

(*c*) " Organisation scientifique du Travail," is the complex of the co-ordinated action the object of which is to achieve and maintain the optimum arrangement of work in any undertaking or any administrative or other service, public or private.

III—RATIONALISATION.

(*a*) Rationalisation in general is any reform tending to replace habitual antiquated practices by means or methods based on systematic reasoning.

(*b*) Rationalisation in the narrowest sense, is any reform of an undertaking, administrative or other service, public or private, tending to replace habitual, antiquated practices by means and methods based on systematic reasoning.

(*c*) Rationalisation in a wider sense, is a reform which takes a group of business undertakings as a unit and tends to reduce the waste and loss due to unbridled competition by concerted action based on systematic reasoning.

(*d*) Rationalisation in the widest sense, is a reform tending to apply means and methods based on systematic reasoning to the collective activities of large economic and social groups.

YORKSHIRE COUNCIL FOR FURTHER EDUCATION

Openings in the Textile Industry for Secondary School Students

In view of the wide variety of processes and the different systems operating in different branches of trade, it is difficult to make general statements on the subject of employment in the Wool Textile Industry. It may, therefore, be useful to give a brief outline of the structure of the industry in its various branches in order that references in subsequent paragraphs to types of employment may be understood in their proper perspective.

The division of the industry into the Woollen Section on the one hand, and the Worsted Section on the other, is fundamental, although it is true that there are a few firms which manufacture both woollen and worsted yarns and fabrics. Firms in both sections of the trade are to be found in most districts, but, speaking generally, it may be said that the woollen industry predominates in the Heavy Woollen Area, the Colne Valley, Morley and Leeds, while worsted yarn and cloth manufacture is carried out in Bradford, Halifax, Huddersfield, Keighley and Leeds districts.

The characteristic of the Woollen Industry from the point of view of employment is that all processes from the sorting of the wool to the finishing of the fabric are carried out by one and the same firm. The same firm may employ wool sorters, wool scourers, blenders and colour mixers, carding operatives, piecers, mule-spinners and spinning overlookers, weavers (male or female according to the locality), weaving overlookers and loom tuners, dyers and finishers, and cloth designers, in addition to a staff of wool buyers and office workers.

In the Worsted Industry, while a number of firms carry out all the various processes, most of the trade is divided into three main sections:—

(i) Wool Merchanting and Top Making, including Combing which is mainly done on commission ;

(ii) Spinning ;

(iii) Cloth Manufacturing—including Dyeing and Finishing which is mainly done on commission.

In the Wool Merchanting and Top Making section posts are available from time to time as wool buyers or top salesmen. The first step is to learn wool sorting which may entail premium apprenticeship. Salesmen are also employed in the Spinning and Cloth Manufacturing sections. In the latter section piece examiners are also required. For all salesmen attendance either at part-time day or evening technical courses is advisable. Overlookers and others in minor official positions in Wool Combing, Worsted Spinning and Manufacturing, are normally recruited from the operative staff. To prepare for these posts attendance at evening technical courses or, if possible, part-time day technical courses is necessary.

In some instances boys may have family connections in the industry and thus have no need to seek posts. Such boys might be advised to take full-time technical courses or, alternatively to spend part of their time in the works and the remainder at the technical college.

For boys who are well qualified in Mechanics and Chemistry there are fairly good prospects with Dyers and Finishers or in the Dyeworks of a Woollen Mill.

For boys and girls with creative imagination there are openings—either on the staff of a firm or as free-lance designers—in the design of decorative woven and printed fabrics and carpets. For this work a good art training is necessary and, in addition, sufficient technical knowledge to appreciate the limitations imposed by the methods of manufacture and reproduction. In this branch of work also contact with the industry as early as possible is highly desirable since the production of a design which meets the requirements of industry involves intimate acquaintance with prevailing fashions in the markets of the world.

There are also remunerative positions as designers of worsted fabrics for men's and women's wear. Since, however, the effect of these designs depends on such matters as the type and quality of fibre used, the twist of the yarn and the structure and treatment of the fabric, long experience at the mill coupled with a highly technical course of scientific training is essential.

Finally it should be remembered that there are fairly frequent and serious fluctuations in all branches of the textile trade from year to year and even over shorter periods. To keep pace with the state of trade it is necessary to be in regular contact with trade organisations and the suggestion is put forward that Head Masters should keep in close touch with local trade advisory committees to keep themselves informed of the demand from time to time in the different branches of the industry.

EDUCATION OFFICE, LEEDS. *October,* 1937.

Wool Industries Research Association. Report of the Director of Research, 1936-1937.

As in December, 1936, the Director of Research, Wool Industries Research Association, has issued a review of recent progress. The object is to acquaint the section of the industry not partaking in the Association's work with the activities of the Association and its scientific staff.

Regret is expressed that the scheme for a statutory levy on the industry, to be devoted to the financing of research work, met with insufficient support to justify the introduction of an enabling bill into Parliament. Though the proposition has had to be dropped for the present, the work of appealing to the industry for further support still goes forward. The late Lord Rutherford and Sir Clement Hindley addressed the Association in this respect on the occasion

of the Annual Luncheon in April last. In August a manifesto was issued over the signatures of about one hundred prominent wool firms. The report ends with the following paragraph. "It is pleasant to be able to conclude this Report on a note of mild optimism. The voluntary shouldering of an increased burden in the financing of research by that part of the industry who are our convinced supporters is an incentive to redoubled efforts on the part of the staff, and at the same time an example to that section which refuses to participate."

The body of the report naturally deals with the progress of the work in the laboratories and its application in the mills. The processes designed to render wool unshrinkable are again discussed and their intrinsic empirical nature is stressed. Fundamental work on this subject is going forward. Wool bleaching comes into a somewhat similar category and here, also, even at the risk of being late in the field, the importance of pursuing strictly scientific work is stressed. Until the foundations have been securely laid satisfactory building cannot proceed.

Of considerable interest is the paragraph dealing with the rubberising of wool. Taking advantage of the fact that wool behaves as an acid or a base according to its treatment and environment, it has been found possible to combine wool and rubber. Application for patents to cover the rubberising of yarn in hank form without matting has been made. The processes permit of the production of strong yarns with low twist, water repellance, moth proofing, etc.

Fundamental investigation on the measurement of wool fineness proceeds, and work has begun on the difficult subject of woollen carding. Statistical criteria alone can determine the quality of the work in this important process and the collection of the necessary data will be a long and perhaps wearisome task.

The subject of oils which may be used instead of olive oil in the making of tops is still being actively studied. The translation of laboratory results into practice through the medium of large scale mill trials is essentially slow if it is to be thorough.

THE
Journal of the Textile Institute

VOL. XXVIII—1937

PROCEEDINGS—NAME INDEX

In this Index (R) indicates that the matter is the subject of a Review.

THE JOURNAL
of the
TEXTILE INSTITUTE

VOL. XXVIII—1937

TRANSACTIONS AND INDEX

THE JOURNAL OF THE

TEXTILE INSTITUTE

TRANSACTIONS

1.—THE CAUSE AND AVOIDANCE OF WARP SHADOW STRIPES IN DAMASK CLOTHS

By H. Boffey

(Linen Industry Research Association.)

SUMMARY

The paper which follows describes the results of an investigation into the cause of a fault in a finished damask table-napkin. This fault consists of a series of " shadow " stripes of uniform width and parallel to the warp. The origin of these stripes is shown to be the application of systematically uneven tensions in the warp yarns during weaving due to the particular method of gaiting the loom involved in this case. The correct method for avoidance of the fault is suggested and practical results confirm the findings.

An appendix is added which gives a simple formula for calculating the extension in a warp yarn at any point in the pick cycle.

INTRODUCTION

The investigation about to be described was the result of an enquiry by a member firm as to the reason for the presence in a finished table-napkin

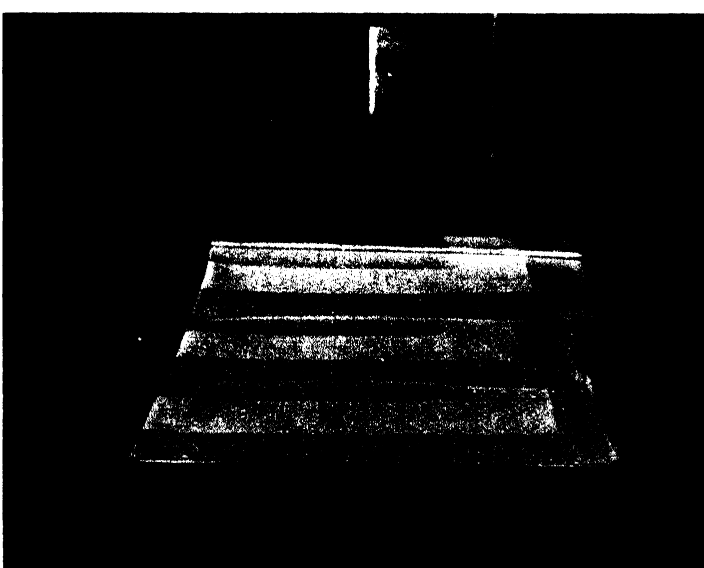


Fig. 1.

of prominent and unsightly bands or stripes of light and shaded portions running parallel to the warp. The napkin in question was a 5-leaf sateen woven on a full-harness machine and the only pattern was a large square satin band roughly two inches wide and set in about an inch and a quarter from each of the four edges of the cloth. The portion A of the photograph in Fig. 1 clearly shows the "shadow" stripes complained of. The firm involved gave the following answers in response to enquiries; the fault

(*a*) happens usually in napkins and not in tablecloths.
(*b*) is found in cloths woven both on full-harness and Bessbrook machines.
(*c*) is found both in 5-leaf and 8-leaf cloths.
(*d*) is present usually in better quality cloths and is most pronounced in "plain" cloths with large satin cross-borders such as the one examined above.

Back of Cloth.

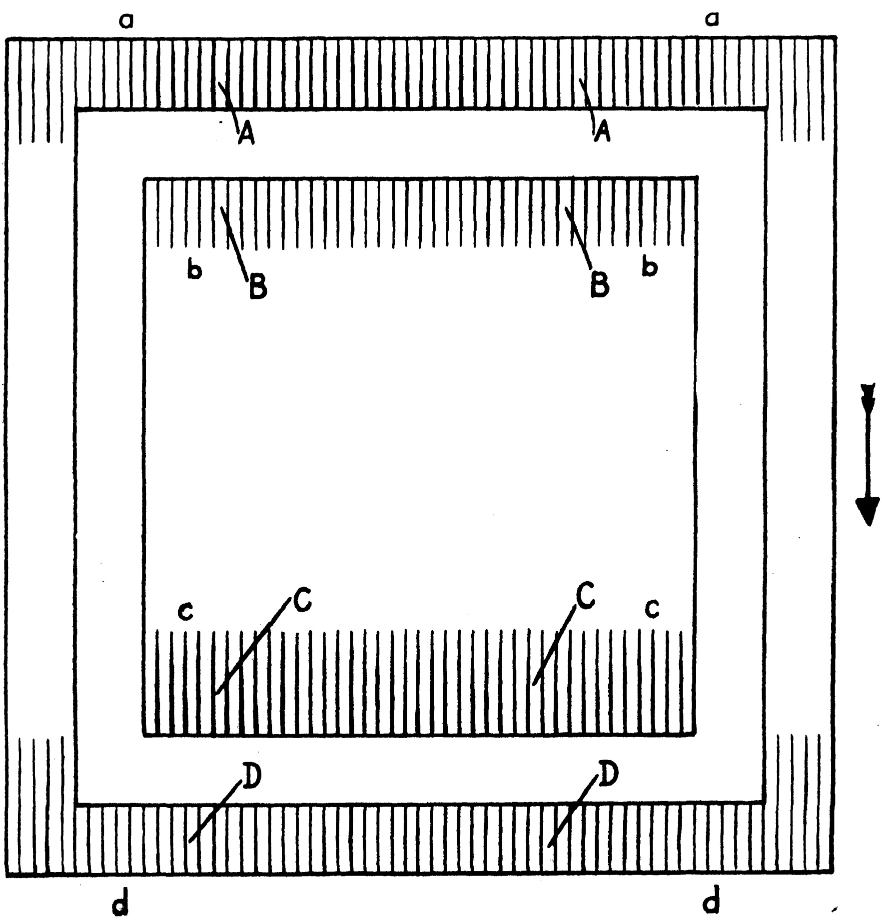


Fig. 2a.

With regard to (*a*), since this investigation was made, examples have been observed of what seemed to be the same fault in tablecloths in use and after laundering. In fact there is no apparent reason from the evidence as to the cause why the fault should be more prevalent in napkins than in tablecloths.

With reference to (*b*) and (*c*) the portion C of the photograph in Fig. 1 shows the shadow stripes appearing on an 8-leaf napkin woven on a Bessbrook machine and although they are not as prominent here as upon the 5-leaf full harness cloth they are still quite pronounced enough to be unsightly.

INVESTIGATION OF THE CAUSE

An idea of the distribution of the " shadow " stripes in the 5-leaf napkin can be gathered from Figs. 2a and 2b which represent a view of the back

FRONT OF CLOTH.

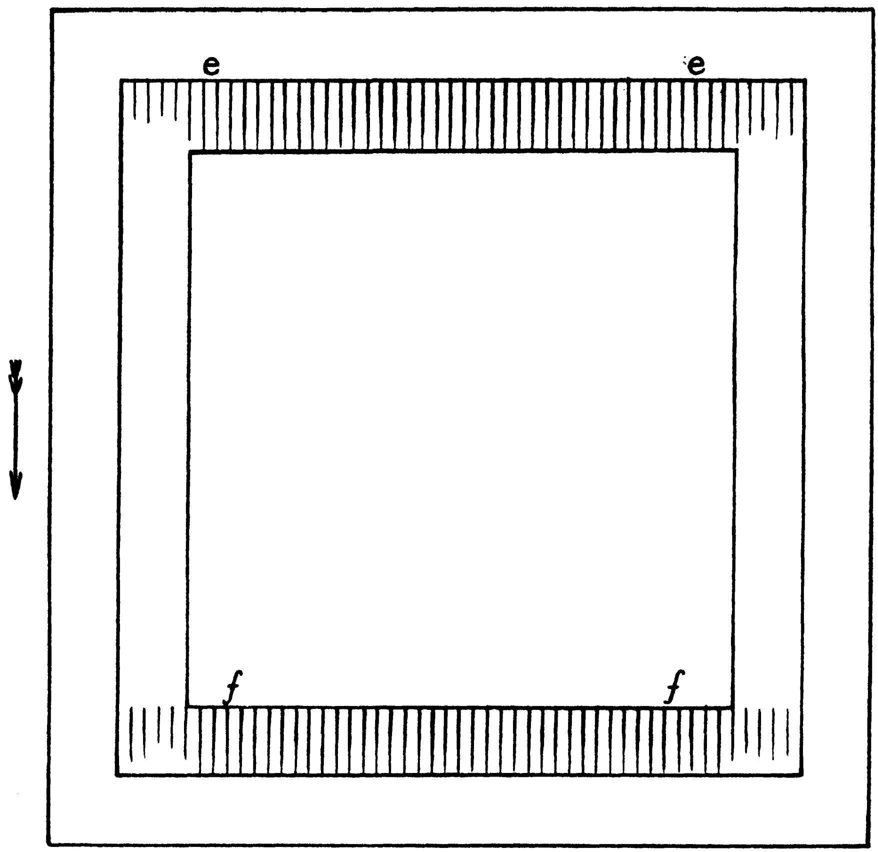


FIG. 2b.

and the front of the cloth respectively. The stripes are most pronounced in the parts with long weft floats and are apparent in the " ground " from aa to bb and from cc to dd on the back of the cloth and in the cross-borders at ee and ff on the front of the cloth. It is attempted to show in the figures to what distances the stripes extend and how strong or weak they are in various parts. Thus on the back of the napkin although there is a suspicion of the presence of the fault the whole way down the cloth the stripes are very faint near the middle, being most pronounced around the two cross-borders ; they are slightly stronger in the sections AA and CC than in the sections BB and DD and extend further into the centre of the cloth at cc than at bb.

On the front of the napkin the stripes extend across both cross-borders except at each side where the warp-ways satin bands join up, here they are not so definite. Also they are stronger near the top edges ee and ff of the cross-borders than near the opposite edges. The stripes are not obvious at the sides of the cloth either in the pattern or the ground.

Four Weft Yarns from Various Places

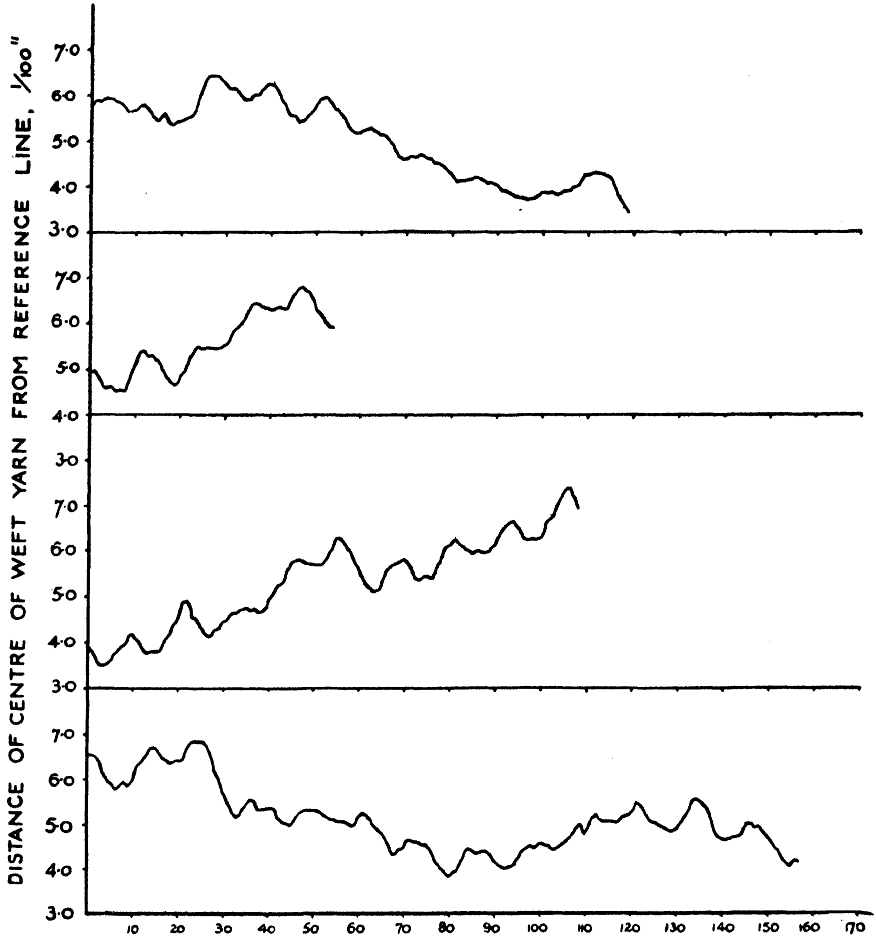


FIG. 3.
Consecutive Warp Ends.

A more detailed examination of the stripes showed that these were apparently very regularly spaced and there were roughly $31\frac{1}{2}$ complete ones, i.e., dark and light portions, in 5 inches width of cloth. The number of warp ends per inch was $75\frac{1}{2}$ and therefore the average number of ends involved in one stripe (dark and light halves) was $75\frac{1}{2} \times 5 \div 31\frac{1}{2}$, almost exactly 12. In any part of the napkin where the fault was pronounced each pick of weft yarn assumed a slight and apparently regular wavy form and the general result was also a regular wave or " break " in the twill lines which was very distinct when the cloth was viewed with the light in certain directions. By using a travelling microscope with a micrometer scale in the eyepiece

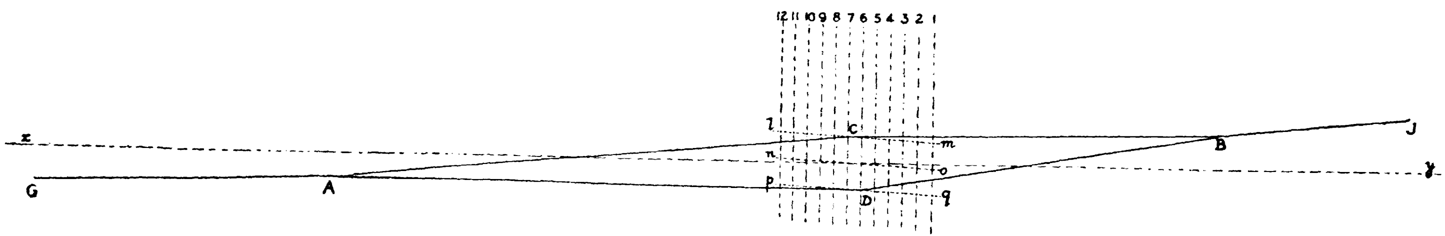


FIG. 4.

G is back shell ; A is front lease-rod ; B is fell of cloth ; J is breast beam ; ACB, ADB are warp yarns in top and bottom lines of shed at beat-up ; 1 to 12 are harness cords ; lm is level of mails in top line of shed at beat-up ; pq is level of mails in bottom line of shed at beat-up ; no is level of mails when shed is fully closed ; xy is a horizontal line through centre of no.

arranged at right angles to the direction of traverse of the microscope, this traverse being along the line of a weft pick, it was possible by moving the eyepiece scale progressively from one warp end to the next to read off the distance between the centre of the weft yarn and a fixed reference line, say the zero of the scale. When these distances were plotted against number of warp end as is shown in Fig. 3 the result was a general idea of the position assumed by the weft in the cloth. The tendency of this weft to lie in a wavy form with a fairly well-defined wave-length of twelve warp ends confirmed the impression already obtained that the stripes observed parallel to the warp of the cloth are due to an optical effect, the basis of which is the arrangement of the weft picks in wavy lines whose crests from one pick to the next all coincide along warp ends spaced twelve ends apart.

Under the circumstances the only method by which the weft yarn could have been placed in a wavy form in the cloth was by its being beaten-up in this manner due to a variation in warp tension across the napkin at the moment of beating-up and this variation must have been systematic, the tension being greatest on warp yarns twelve ends apart. Along these warps each weft pick would be beaten-up further into the cloth than along intermediate warps under a lower tension, and if these tension differences were roughly maintained for a large number of picks the result would be as obtained in the napkin under consideration.

It was ascertained that the cloth was woven on a 12-row 600-needle machine and some details of position of back shell, breast beam, harness mails, etc., were measured at the loom. From the measurements made it was a simple matter to construct diagrams in the form of cross-sections in a vertical plane from front to back of loom showing the path of each warp yarn between back shell and breast beam for any row of the harness mails from No. 1 to No. 12. One such typical diagram is shown in Fig. 4, it refers to a time during the weaving of the cross satin band, that is four warp lifted, one left down, and to a moment when the reed was fully forward at the beat-up. In this diagram just two warp yarns are shown, one through mail

Table I

Warp Yarn Extensions in Inches.

Harness Mail No.	Weaving on Cross Band.		Weaving off Cross Band.	
	Warp up.	Warp down.	Warp up.	Warp down.
1	·004	·176	·014	·132
2	·006	161	·017	·118
3	·008	·147	·021	·106
4	·010	·134	·025	·095
5	013	·122	·029	·085
6	·016	·110	·034	·076
7	·020	·100	·039	·067
8	·024	·090	·044	·059
9	·028	·081	·050	·052
10	·033	·073	·056	·046
11	·038	·065	·062	·040
12	·043	·058	·069	·035

No. 6 down and one through mail No. 7 up ; for the purposes of this investigation it is not necessary to take account of the arrangement of the yarns

with respect to the lease rods (single-end leasing was employed), it is sufficient to assume all the warps come to the mails from the front-centre of the front lease rod. As is clear from this diagram, in the loom concerned in this investigation a "troughed" shed was employed, the back shell was appreciably lower than the breast beam, and the harness was sloped uniformly downwards from back to front (mail No. 12 was $\frac{1}{4}$in. higher than mail No. 1 at closed shed). From the diagram as shown in Fig. 4 the lengths of the various warp yarns through the different harness mails with the reed in the beat-up position were measured and by subtracting from these lengths the direct distance between front lease rod and fell of cloth the values for the extension of each warp in the top or in the bottom shed at beat-up were obtained. These measurements are given in Table I. It was then assumed that at the moment of beating-up the weft the tension in a warp yarn was proportional to its extension as given in Table I. This is a simple method of arriving at the values for single warp tension but it is doubtful if it can be completely accurate; in practice each warp end undergoes a cycle of operations repeating every five picks and at any one beat-up the immediate previous "history" of each warp will be different. To deduce mathematically the exact variation of tension in a warp end would probably be a most complicated business, and it would be much easier to follow the process experimentally by means of a single end tension measuring device. For

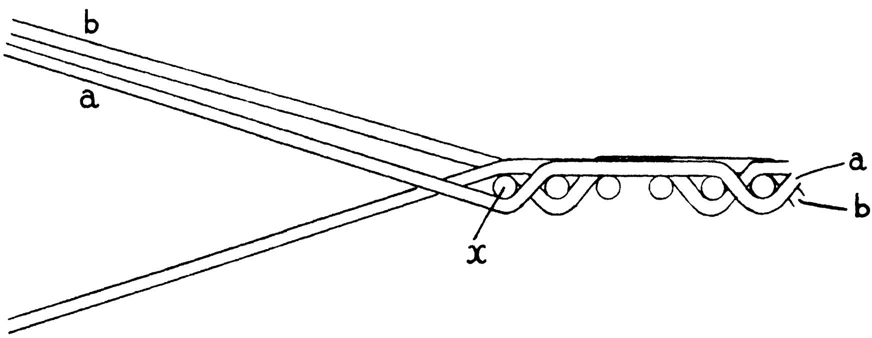


FIG. 5.

the present purposes, however, it will be sufficiently accurate to take the extension as given in Table I as indicative of the yarn tensions developed. It should be noted here that in this case, that is, weaving on the cross satin band, each warp yarn does at least go into or very near to the straight-through-from-lease-rod-to-fell position at one instant during each pick. In the case of weaving off the cross satin band discussed later each warp yarn goes into the "straight-through" position only twice in every five picks and for the remaining three picks in the cycle it remains in the same position in the bottom line of shed. Turning again to Table I, it is clear that from mail No. 1 to mail No. 12 there is a steady increase in tension of the warp yarns in the top shed and a steady decrease in tension of these in the bottom shed. Now at the moment of beating-up a weft pick (suppose it is x in Fig. 5) the warp yarns which immediately oppose its motion into the body of the cloth are those such as *a* which have just gone up from the bottom into the top line of shed and those such as *b* which are now in the top line of shed but were down in the bottom line for the preceding pick. If for instance

the weft pick x is the third pick in the point paper design in Fig. 6 (which represents the warps in batches of twelve, each batch connected with one row of twelve mails from front to back of the harness), the warp yarns against which this weft is immediately being beaten-up are $3_1\ 5_1\ 8_1\ 10_1\ 1_2\ 3_2\ 6_2\ 8_2\ 11_2\ 1_3\ 4_3\ 6_3\ 9_3\ 11_3$, all being in the top line of shed. Since according to the measurements set out in Table I, the tensions in these ends will vary in a regular manner in cycles of 12 ends from 1_1 to 12_1, 1_2 to 12_2 and so on, it is clear that the particular weft x will be laid in the cloth in a slightly wavy form with a regular wave-length of twelve warp ends. Although the next weft pick to be inserted, the fourth in Fig. 6, will be opposed by a different

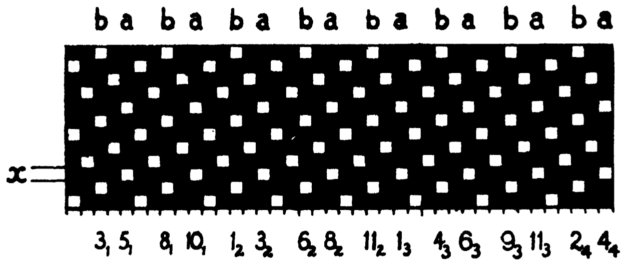


Fig. 6.

set of warp yarns, viz. $2_1\ 5_1\ 7_1\ 10_1\ 12_1\ 3_2\ 5_2\ 8_2\ 10_2\ 1_3\ 3_3\ 6_3\ 8_3\ 11_3$, all in the top shed, the same reasoning as above still holds and the wavy weft will be apparent. Moreover since the tension in any one warp in the top line of shed, although different from that of its neighbours, will always be sensibly the same, it will be clear that the twelve-end long waves in the various weft picks will all be in the same phase with respect to distance across the cloth, that is to say, a crest of a wave in one pick will coincide with a crest of a wave in the next pick and so on, as is shown in Fig. 7. It is this arrangement of the weft yarns which causes the reflection of light to the eye from portions such as n to be different from that from portions such as m and so to give rise to apparent dark and light stripes parallel to the warp. Seeing that it is only the weft yarns and not the warp which are involved in this variation of reflection of light, the stripes will obviously be more prominent on the side of the cloth with the long weft floats than on the other side with long warp floats.

The above argument has referred to the case of weaving on the cross satin bands. Somewhat similar considerations apply to the case of weaving off the cross satin band, that is the whole of the centre of the cloth and the portion near each hem. The values of the extensions of the warp yarns involved at the beat-up position of the reed are given in Table I and it will be seen that as in the previous case these values slowly increase from harness mail No. 1 to mail No. 12 for warps in the top shed line and decrease continuously from mail No. 1 to mail No. 12 for warps in the bottom shed line. There is perhaps not as much justification for assuming the tension values in the yarns as proportional to these extension measurements in the present instance as in the former case for the reasons already given above, but on the whole there is little doubt that broadly the same trend of variation in tension will be present. The warps which now immediately obstruct the beating-up of any pick into the body of the cloth are always in the bottom line of shed.

That the analysis of this problem developed above is not complete is obvious from the fact that the "shadow" stripes are not so prominent in some parts of the cloth as in others. According to the above reasoning the stripes ought to be seen uniformly strong over the whole of the napkin whereas they practically disappear in the centre of the cloth and also vary in intensity in other parts. The occurrence of the stripes is undoubtedly amongst other things connected with the change-over from weaving off the cross satin band to weaving on this band and then off it again. In other words either the variations in warp tension deduced earlier in this paper as being the ultimate cause of the striping are not sufficiently great in themselves to produce serious weft distortion but require to be enhanced by a complete change-over in the general tension distribution such as occurs when going on or off the cross band, or the tabulated variations are great enough as such to cause serious weft distortion when newly present after a change-over in the weaving but gradually disappear as weaving proceeds under any one set of conditions, e.g. in centre of napkin. That the redistribution of warp tension at a change-over of lift in the weaving is general

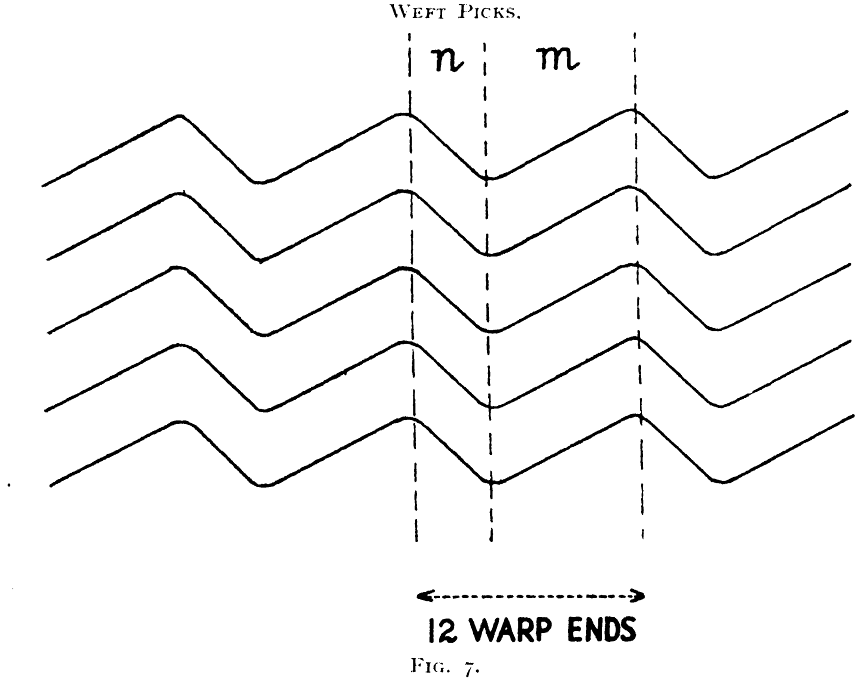


FIG. 7.

across the whole width of the napkin is shown by the fact that the sides of the cloth where the pattern does not change display the warp stripes at the top and bottom of each napkin as shown in Fig. 2a. The whole problem is rather too complicated to allow of complete explanation without the aid of some actual tension measurements on single warp ends.

METHOD OF PREVENTION

It was easy to find a method of preventing the occurrence of the shadow stripes fault when it was borne in mind that the variations in the lengths of the paths of the warp yarns through the various harness mails in the

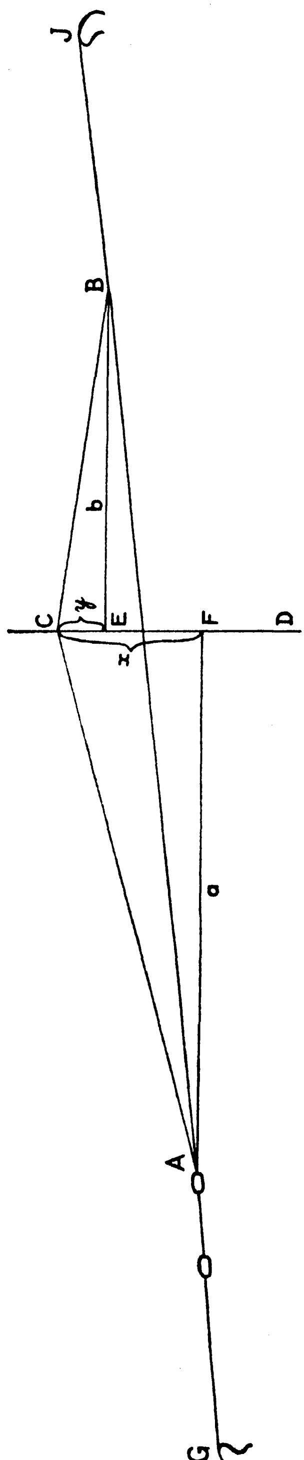


FIG. 8.

loom concerned in this investigation were due mainly to the fact that the general line of warp sloped upwards from back shell to breast beam while a line drawn through a row of twelve mails at closed shed sloped downwards from back to front. This can clearly be seen in Fig. 4. In order to even out the extensions of the various warps during shedding it would be necessary to make the general warp line and that through the harness mails from back to front parallel. There are many other considerations, however, which have to be taken account of such as direction of blow of reed at the beat-up with respect to plane of cloth, maintenance of a " clean " shed, good grounding of bottom line of warps on shuttle race, and so on. Actually in the present instance it was recommended to the manufacturers involved that the back shell and breast beam be undisturbed and that the back harness cords be lengthened one quarter of an inch, the front ones shortened by one quarter of an inch and the intermediate ones altered by suitably proportionate amounts to preserve the levelness of the mails, also that the depth of shed as a whole be increased by one quarter of an inch. This would make yarn tensions in the top line or in the bottom line of shed much more uniform than before and would also improve the overall grounding of the bottom warps on the shuttle race. Although the shed would not be as " clean " for the passage of the shuttle as before it would still be as deep, and despite the general increase in amount of shed tending to give higher warp tension the more uniform distribution of the latter would keep the maximum reasonably low. Following the above recommendation a certain amount of alteration was made to the lengths of the harness cords, exactly how much is not quite certain but definitely not as much as suggested. The result was an improvement in the appearance of the cloth as is seen at B in Fig. 1 which shows a photograph of a portion of a finished napkin woven subsequent to the carrying-out of this alteration to the loom. This portion of the photograph compares directly with that at A (in the same Fig.) of the original napkin and the diminished prominence of the warp stripes in the former is obvious. There is little doubt that if the loom alterations had been undertaken as completely as recommended the fault in the cloth would have been eliminated. As it was the manufacturers stated that the improvement actually obtained was good enough to make the cloth saleable so there the matter ended.

Mr. J. C. McIlveen made the various measurements at the loom used for the above drawings and calculations and also the travelling microscope readings for evaluation of the weft distortion in the cloth. Dr. Spencer-Smith made the calculations of yarn extensions in the case of the arrangement of harness cords finally suggested to even up the warp tensions.

APPENDIX

Formula for Calculating Extensions in Warp Yarns

Suppose Fig. 8 to represent a vertical cross section through the yarn in the loom from back to front in which G is the line of contact of the warps with the back shell, J is the line of contact of the cloth with the breast beam, A is the front centre of the front lease rod, B is the fell of the cloth, C is the position of a harness mail at any instant, AF is a horizontal line through A meeting the vertical line CD in F, BE is a horizontal line through B meeting CD in E.

Now let distances $AF = a$, $BE = b$, $CF = x$, $CE = y$. (x is $+ ve$ when C is above F; y is $+ ve$ when C is above E).

Then $AC^2 = a^2 + x^2$

and $\therefore AC = (a^2 + x^2)^{\frac{1}{2}} = a\left\{1 + \left(\frac{x}{a}\right)^2\right\}^{\frac{1}{2}}$

Expanding this as a binomial series we get

$$AC = a\left\{1 + \tfrac{1}{2}.\frac{x^2}{a^2} + \tfrac{1}{2}.(-\tfrac{1}{2}).\tfrac{1}{2}.\frac{x^4}{a^4} + \tfrac{1}{2}.(-\tfrac{1}{2}).(-\tfrac{3}{2}).\tfrac{1}{6}.\frac{x^6}{a^6} + \dots\dots\dots\right\}$$

If x is reasonably small compared with a, we can neglect the terms containing $\frac{x^4}{a^4}$ and higher powers in the above series, and can write

$$AC = a + \frac{x^2}{2a} \qquad \dots\dots(1)$$

Again $BC^2 = b^2 + y^2$

$$\therefore BC = (b^2 + y^2)^{\frac{1}{2}} = b\left\{1 + \left(\frac{y}{b}\right)^2\right\}^{\frac{1}{2}}$$

and by a similar process to the above

$$BC = b + \frac{y^2}{2b} \qquad \dots\dots(2)$$

Again $AB^2 = (a + b)^2 + (x - y)^2$

$$\therefore AB = \left\{(a + b)^2 + (x - y)^2\right\}^{\frac{1}{2}} = (a + b)\left\{1 + \left(\frac{x - y}{a + b}\right)^2\right\}^{\frac{1}{2}}$$

This also expands and simplifies into

$$AB = a + b + \frac{(x - y)^2}{2(a + b)} \qquad \dots\dots(3)$$

The extension of the warp yarn $ACB = AC + BC - AB$

Combining equations (1), (2) and (3) above we get

$$\text{Yarn extension} = a + \frac{x^2}{2a} + b + \frac{y^2}{2b} - a - b - \frac{(x - y)^2}{2(a + b)}$$

$$= \frac{x^2}{2a} + \frac{y^2}{2b} - \frac{(x - y)^2}{2(a + b)} \qquad \dots\dots(4)$$

Received 22/10/36

2.—DETERMINATION OF THE YIELD OF RAW WOOL FROM ITS DENSITY UNDER PRESSURE

By Robert H. Burns and Alexander Johnston
(University of Wyoming.)

It is the general custom throughout the United States to use the term shrinkage of wool when valuing clips of wool or individual fleeces from economic standpoints. The word shrinkage, used in this sense, means the weight that raw wool loses when it is scoured, expressed as a percentage of the original weight.

This lost or discarded material is composed of yolk, dust, sand, particles of excreta, and vegetable matter, such as plant seeds, twigs and leaves. Of these ingredients, only the yolk has any commercial value as a by-product of the wool scouring industry.

Actually, however, the converse of shrinkage, namely, the yield of clean wool, is the important factor. The yield is defined as the percentage of clean wool left in a lot after scouring.

For many years the problem of accurate determination of yield has been steadily increasing in economic significance. From the standpoint of the commercial flock-master a knowledge of the correct yield of his clip of wool is extremely desirable, being conducive to intelligent marketing of the clip and improved methods of flock management. With the realization of the importance of the transmission of hereditary characters a knowledge of the yields of individual sheep is most important to the progressive sheep breeder.

The wool buyer also is faced by the same problem, and, although usually more experienced in judging yield, can err disastrously in his estimation.

The current methods employed in determining the yield of raw wool, other than by estimation based on visual examination, are rather laborious although fairly accurate. In execution these methods differ somewhat in technique and process, but all follow the same general steps, namely (*a*) sampling the clip or fleece, (*b*) weighing the samples, (*c*) scouring, by emulsion or solvent processes, (*d*) drying, and, (*e*) determining the yield of the wool when constant air-dry weights have been obtained. These methods, although found to be fairly satisfactory when practised in the wool laboratory, are seldom employed by sheep owners, partly through their inability to realize the economic importance of yield, and partly because of the cost of the apparatus and the laborious routine and time necessary to determine yield.

The necessity for a method of yield determination which is comparatively rapid, accurate and economical has long been realized. A satisfactory method, taking say ten minutes to complete, would be of inestimable value to both the wool grower and the wool buyer in determining the value of the wool clip.

With this end in view, the principles employed in this experiment were first conceived by Dr. J. I. Hardy, Senior Animal Fibre Technologist of the Bureau of Animal Industry, U.S.D.A., Washington, D.C. He observed large differences in apparent density of light-yielding and heavy-yielding wools, especially in fleeces from bales of wool that had been baled under high pressure and allowed to stand for a considerable time before opening. By submitting samples of raw wool to certain pressures and measuring the resulting volumes, he was able to show that there was a very significant relationship

between the density under pressure and the clean wool content. He proved that when definite weights of raw wools of the same grade but different yields were subjected to the same pressure, the light-yielding wool occupied less space than the heavy-yielding wool. By this method Dr. Hardy was able to demonstrate that the clean wool content, or yield, of raw wool could be estimated within approximately five per cent. of the actual yield.

The writers in their investigations endeavoured to devise a method by which yield predictions could be made more accurately by means of compression.

FIG. 1

The wools used in this experiment were composed of four composite samples of sorted, scoured wool from the fine, half blood, three-eighths and quarter blood grades, twenty-six fleeces and eight general or clip samples from range bands of sheep running in southern Wyoming. The fleeces were selected according to grade from the general run of fleeces going from the shearing floor to the sacking room. The general samples were taken by a method developed by the Wool Department of the University of Wyoming, by which a representative handful of wool, composed principally of shoulder, side, and back wools, is taken from each of fifty fleeces shortly after shearing of the band commences and from fifty fleeces shortly before the shearing finishes.

In the laboratory the fleeces were longitudinally divided after the tags had been removed. The general samples were sorted and each sort was halved. The samples were then ready to be compressed.

The compression apparatus used in the experiment is shown in the accompanying illustration, Fig. 1, and was the original machine used by Hardy. It was kindly lent to the Wyoming Experiment Station by the Bureau of Animal Industry, Washington, D.C.

The machine assembly consists of an ordinary platform scales of 2,000 pounds capacity, having a vertical rectangular iron frame built over the platform and clamped to the base of the scales. A long iron bench screw passes vertically through the centre of the upper beam and can be raised or lowered by turning the iron wheel below the beam through which the screw passes.

A thin brass disc is set horizontally on the upper end of the bench screw close to a vertical metre stick mounted on the upper part of the frame. Thick oak discs, which fit the compression cylinders, can be bolted to the lower end of the bench screw.

Two brass cylinders were used to hold the wool when being compressed. One cylinder, 13 inches high and $7\frac{1}{2}$ inches inside diameter, was used to hold the smaller samples of wool, and the other cylinder, 36 inches high and approximately 8 inches inside diameter, was used for the larger samples.

After considerable preliminary investigation, a method of compression technique was devised which can be briefly outlined as follows.

The sample of raw wool was packed by handfuls in the compression cylinder, care being taken to insure as uniform a mass as possible. The packed cylinder was then placed on the scales platform and the counterbalance weights for the force to be exerted on the wool were suspended from the beam. This force was applied by depressing the disc on the end of the bench screw by turning the wheel. The tipping of the weight beam of the scales indicated that the desired force had been applied.

Early in the investigation it was found that the springiness of the wool fibres and the friction of the raw wool on the inner surface of the cylinder did not allow a uniform subsidence of the wool mass under pressure. Thus the elapsed time between applying the force and taking the reading is very important.

Fig. 2 shows the effect of elapsed time upon the volume readings. The volume of wool under pressure decreases rapidly at first and then at a much slower rate. After 13 minutes of constant pressure the curve has flattened out, indicating that the volume has more nearly reached a state of stability. All samples showed a similar type of curve regardless of the amount, type, or condition of the wool in the sample. The curves in the figure also show that a force of 2,000 pounds is more rapid and effective in overcoming the springiness and friction of the wool samples. It would be quite possible to obtain readings more quickly by employing greater forces than 2,000 pounds ; this was not possible with the B.A.I. apparatus. Thirteen minutes was selected as the standard elapsed time for use in the compression tests. The depth of the column of wool under compression was then taken from the metre stick at a point directly opposite the brass indicator disc on the upper end of the bench screw.

Two different pressures were used. When using the 13-inch cylinder a force of 500 pounds applied to the wool gave a pressure of 11·37 pounds per square inch, and a force of 2,000 pounds gave a pressure of 45·50 pounds per square inch. When using the 36-inch cylinder an applied force of 500 pounds meant a pressure of 10·58 pounds per square inch, and a force of 2,000 pounds corresponded to a pressure of 42·32 pounds per square inch. These variations were due to the differences in diameter of the tall and short cylinders.

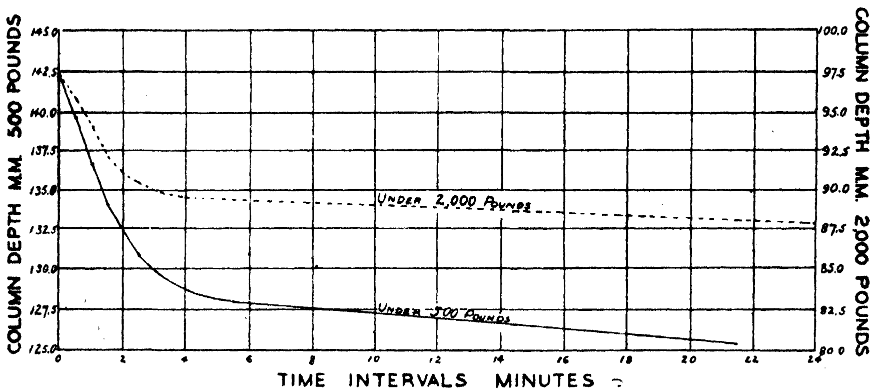


FIG. 2

The entire wool samples were first subjected to a force of 500 pounds and then to a 2,000-pound force. The loose dirt was then extracted from the samples by passing them through a cone duster (breaker) and they were again subjected to the 2,000-pound force.

After compressing, the wool samples were scoured in order to obtain the yield of clean wool.

RESULTS OF THE EXPERIMENT.

Results with Entire Fleeces. In order to reduce the measures of volume of the various samples to a comparable basis, the index figure of volume per unit of weight, or the density, was chosen. In order to make this perfectly clear to the reader, it may be explained that the term density is used here to mean the volume per unit weight of wool when under a given force after 13 minutes of continuous application of that force. The density differs under different forces.

The experimental data relating to the fleeces will be found in Table I, where the fleeces are arranged by grade in ascending order of total yield.

A casual examination of the first five columns of this table reveals the fact that the density of the raw wool is roughly directly proportional to the total yield, for, in the majority of cases, as the yield increases there is a corresponding increase in the volume of one gram of wool in the different fleeces.

This concept was found to be mathematically correct to a very significant degree in the cases under both the 500-pound and 2,000-pound forces, but the relationship between apparent density under pressure and total yield was more consistent under the 2,000-pound force. This will be seen from the results given at the bottom of Table I. From these results it is possible

to predict the yield of a certain lot of fleeces, prepared and compressed in the manner already explained, within 2·85 per cent. of the true yield in 68 cases out of 100 when subjected to a force of 2,000 pounds.

Table I
Fleeces and Volume Indexes

Fleece No.	Grade.	Total yield. %	Volume of 1 gram of Wool. Before Dusting. Force 500 lbs. c.c.	Volume of 1 gram of Wool. Before Dusting. Force 2,00 lbs. c.c.	Volume of 1 gram of Wool. After Dusting. Force 2,00 lbs. c.c.	Yield after Dusting. %
A1	Fine F. C.	26·6	2·05	...	...	...
A6	Fine F. C.	26·8	1·94	1·32	1·42	32·4
A3	Fine F. C.	27·2	2·10	1·47	1·67	35·7
A2	Fine F. C.	28·1	2·13	...	...	...
A4	Fine F. C.	30·1	2·37	1·62	1·83	40·5
A5	Fine F. C.	32·0	2·31	1·57	1·85	44·4
B2	½ Blood S.	26·1	1·85	...	...	...
B3	½ Blood S.	26·4	2·00	1·40	1·58	35·8
B4	½ Blood S.	30·7	2·15	1·51	1·75	42·4
B6	½ Blood S.	31·4	2·23	1·53	1·74	41·7
B1	½ Blood S.	31·7	2·47	...	...	...
B9x	½ Blood F. C.	35·6	2·25	1·55	1·79	44·9
B7	½ Blood S.	35·9	2·37	1·60	1·87	47·5
B5	½ Blood S.	35·9	2·47	1·66	1·96	48·8
B8	½ Blood S.	36·8	2·20	1·53	1·66	43·1
C6	⅜ Blood S.	30·4	2·25	1·55	1·85	42·6
C4	⅜ Blood S.	32·8	2·32	1·58	1·81	44·3
C5	⅜ Blood S.	35·0	2·50	1·70	2·10	51·6
C1	⅜ Blood S.	35·9	2·32	...	...	...
C3x	⅜ Blood S.	37·0	2·57	1·73	2·11	52·3
C2	⅜ Blood S.	37·3	2·27	...	...	...
D2	¼ Blood S.	31·1	2·17	...	...	...
D1	¼ Blood S.	37·5	2·37	...	...	...
D4	¼ Blood S.	40·1	2·42	1·68	1·89	50·0
D3	¼ Blood S.	47·3	2·65	1·84	2·13	58·0
E2	Low ¼ Blood S.	47·4	2·35	1·69	1·91	...
E1	Low ¼ Blood S.	70·6	3·00	2·11	2·25	...

Before Dusting :
Force 500 pounds. Coefficient of correlation = 0·81 ± 0·05.
Force 2,000 pounds. Coefficient of correlation = 0·85 ± 0·05.
Regression standard error of estimate = 2·85 per cent.

After Dusting :
Force 2,000 pounds. Coefficient of correlation = 0·93 ± 0·02.
Regression standard error of estimate = 2·44 per cent.

The last two columns in this table represent the data obtained from the fleeces after dusting. The yield figures were procured by taking the weight of the dusted wool as the base in the yield calculations. In actual practice, when the yield of the dusted wool is obtained by this method of compression, the total yield of the raw wool can easily be computed by dividing the weight of the clean wool fibre content by the weight of the dusted wool plus the weight of the dirt.

It is logical to suppose that with the removal of one variable (e.g., loose dirt) that the relationship between the density and yield would be greater, and this is actually the case, for yield predictions can be made by this method, when using dusted wool, within 2·44 per cent. of the actual yield in the majority of cases.

Table II

General Samples and Volume Indexes

Clip No.	Sample No.	Grade.	Total yield. %	Volume of 1 gram of wool. Before Dusting. Force. 500 lbs. c.c.	Before Dusting. Force. 2,000 lbs. c.c.	After Dusting. Force. 2,000 lbs. c.c.	Yield after Dusting. %
3401	2	Fine F. C. ...	26·5	1·81	1·27	1·40	35·1
3403	1	Fine F. C. ...	26·5	1·66	1·18	1·23	32·9
3402	1A	Fine F. C. ...	28·0	1·70	1·17	1·27	34·8
3404	2	Fine S.	28·0	1·60	1·14	1·24	33·0
3403	2	Fine F. C. ...	28·2	1·69	1·16	1·26	33·4
3404	1	Fine S.	28·4	1·69	1·18	1·29	34·8
3402	2	Fine F. C. ...	29·1	1·74	1·27	1·40	35·3
3401	1	Fine S. & F. C....	29·4	1·88	1·29	1·42	37·1
3402	2	½ Blood S. ...	30·0	1·85	1·28	1·48	39·6
3404	2	½ Blood S. ...	30·7	1·77	1·25	1·37	37·9
3402	1	½ Blood S. ...	30·7	1·91	1·30	1·51	41·4
3403	2	½ Blood S. ...	31·0	1·88	1·29	1·43	38·4
3404	1	½ Blood S. ...	31·0	1·90	1·32	1·49	40·9
3403	1	½ Blood F. C. ...	32·1	1·80	1·24	1·37	39·1
3401	1	½ Blood S. ...	33·1	1·89	1·35	1·51	40·9
3402	2	⅜ Blood S. ...	33·8	1·87	1·35	1·54	42·3
3402	1	⅜ Blood S. ...	35·3	1·93	1·38	1·63	48·3
3404	2	⅜ Blood S. ...	35·7	2·10	1·45	1·68	47·4
3404	1	⅜ Blood S. ...	37·7	2·10	1·46	1·61	45·9
3403	1	⅜ Blood S. ...	42·3	2·16	1·54	1·76	52·0
3403	2	⅜ Blood S. ...	42·5	2·11	1·53	1·76	52·4
3402	1	¼ Blood S. ...	40·5	2·09	1·51	1·75	50·7
3402	2	¼ Blood S. ...	40·9	2·25	1·63	1·92	52·0
3403	2	¼ Blood S. ...	48·7	2·47	1·71	1·94	58·1
3403	1	¼ Blood S. ...	52·2	2·55	1·82	2·04	63·7

Before Dusting :
Force 500 pounds. Coefficient of correlation = 0·96 ± 0·01.
Regression standard error of estimate = 2·05 per cent.
Force 2,000 pounds. Coefficient of correlation = 0·97 ± 0·008.
Regression standard error of estimate = 1·73 per cent.

After Dusting :
Force 2,000 pounds. Coefficient of correlation = 0·98 ± 0·005.
Regression standard error of estimate = 1·72 per cent.

This prediction margin can largely be accounted for by the fact that the grades of wool were not uniform in the fleeces. It is well known that a fleece classed as fine may have an appreciable amount of half blood and three-eighths blood wools around the britch, and a fleece classed as three-eighths blood may contain some wool as low as low quarter blood. Several investigators have proved that volume increase under pressure is definitely

associated with increase in fibre diameter. This the writers found to be true, even when using the 2,000-pound force, which, although much more effective than the 500-pound force in overcoming the springiness of the wool fibres, did not totally eliminate the variable. This is one reason why sorted wools should be used in this method of yield prediction.

Results with Sorted Samples. The experimental results with the sorted samples will be found in Table II, where the samples are arranged by grade in ascending order of total yield.

As in the case of the fleeces, it will be seen that increasing total yield is associated with a corresponding increase of density. The relationship is much closer than that shown by the fleeces, as will be seen by comparing the data at the bottoms of Tables I and II. The correlation figures for the sorted samples are remarkably high and closely approach the perfect state of affinity (r = 1·00). These results, as in the case of the fleeces, show that more accurate yield predictions are possible when the sorted samples are dusted before compressing. A prediction of yield based on this method of compression, by which sorted and dusted wool samples are subjected to a force of 2,000 pounds, will be within 1·72 per cent. of the actual yield in the majority of cases. This difference compares very favourably with the results obtained by the best expert judgment of yield, and the results of small duplicate samples as compared with each other and with entire sacks of wool. The evidence proves conclusively that the best results from this method of yield prediction will be obtained when the raw wool samples are carefully sorted and dusted before compressing.

SUPPLEMENTARY WORK WITH BALE PRESSURES

In the spring of 1934 the Wool Department made some preliminary tests on the forces necessary to bale wool and the pressures on different bales of ungraded wool at the Walcott (Wyoming) shearing shed. A compression spring apparatus was made from four nine-inch railroad box-car springs mounted between iron plates and calibrated in the Materials Testing Machine of the Mechanical Engineering Laboratory. Compression figures were obtained from 45 bales of ungraded wool. The total forces ranged from 4,500 to 13,000 pounds with an average of 7,600 pounds. The pressures in pounds per cubic foot of compressed wool ranged from 270 to 803 pounds with an average of 461 pounds. No scouring test results were available on these bales of wool. These tests showed the necessity of sorting raw wool to obtain density figures of some value in predicting the yield of wool. The rather wide range of forces necessary to bale the wool packs to a standard size shows that there is a significant difference of density even in ungraded fleeces.

CONCLUDING REMARKS

Although the experiments of the Bureau of Animal Industry and those at the Wyoming Experiment Station can only be regarded as preliminary tests, the results prove conclusively that it is possible to predict the actual yield of raw wool from its density under pressure within a comparatively small margin. The writers are confident that it is possible further to reduce this margin of error, and towards this end further experimentation will be undertaken at the Wyoming Experiment Station. As the equipment used in this

experiment was rather cumbersome, it is also planned to standardise and simplify the necessary apparatus, so that it will be portable and easily available to wool growers. The reduction of the time element will also be attempted, and this, indirectly, will probably reduce the prediction margin of error by facilitating the processing of a larger number of samples from a lot of raw wool and averaging the results.

Even at the present stage of development the compression of raw wool for the prediction of yield offers a most valuable tool to the wool grower and buyer in appraising a clip of wool. It offers a quick and reliable method of testing yield estimates made by visual examination, and is of mutual benefit to both producers and buyers in offering more definite information upon which to base an appraisal and thus a trading basis can be more easily established. It also offers the producer a method of yield determination, an education in the sorting of wool, and a knowledge of his clip which would be difficult to obtain in any other way. It shows him what he is producing in the way of wool and provides an incentive to improve the uniformity of grade and yield of his clip.

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

3.—AN ABBREVIATED METHOD AND A SUGGESTED CHEAP MECHANICAL DEVICE FOR CALCULATING THE STANDARD DEVIATIONS OF OBSERVATIONS.

By J. L. SPENCER-SMITH and H. A. C. TODD.

SUMMARY

A rapid graphical method of calculating the standard deviation of a set of observations, by means of Galton's " ogive " curve, is described. The " ogive " curve is projected into a straight line by plotting on " probability " paper, and is completely determined for normal distributions by the percentage number of observations which are less than two given values. The standard deviation is read off from the straight line joining these two points. A comparison of the results of the method with the root mean square standard deviation is given and the probable error of the method estimated to be 3·5 per cent. The application of the method as an integrator for routine testing machines is discussed.

INTRODUCTION

When the results of a large number of measurements of some physical quantity show a frequency distribution which approaches closely to the normal frequency distribution the results may be expressed sufficiently completely for most practical purposes in terms of the mean and the standard deviation. The present paper describes a simple and rapid method of estimating the standard deviation of a number of observations with sufficient accuracy for most purposes. The method has the further advantage that it can be applied in the form of a cheap integrator to almost any testing machine. It is felt that the method may be of service to those who have not got the resources of a statistical laboratory at their disposal.

In principle the method is very similar to that of Holcomb and Froman,[1] but was arrived at independently. Although it covers much of the same ground as the above mentioned paper, so far as principle is concerned, the method of graphical application is simpler, and application as a mechanical integrator is also discussed.

Theory of Method.

One of the usual methods of illustrating variation graphically is by the " ogive " curve proposed by Galton.[2] In this method the number of observations having values less than any given value is plotted against

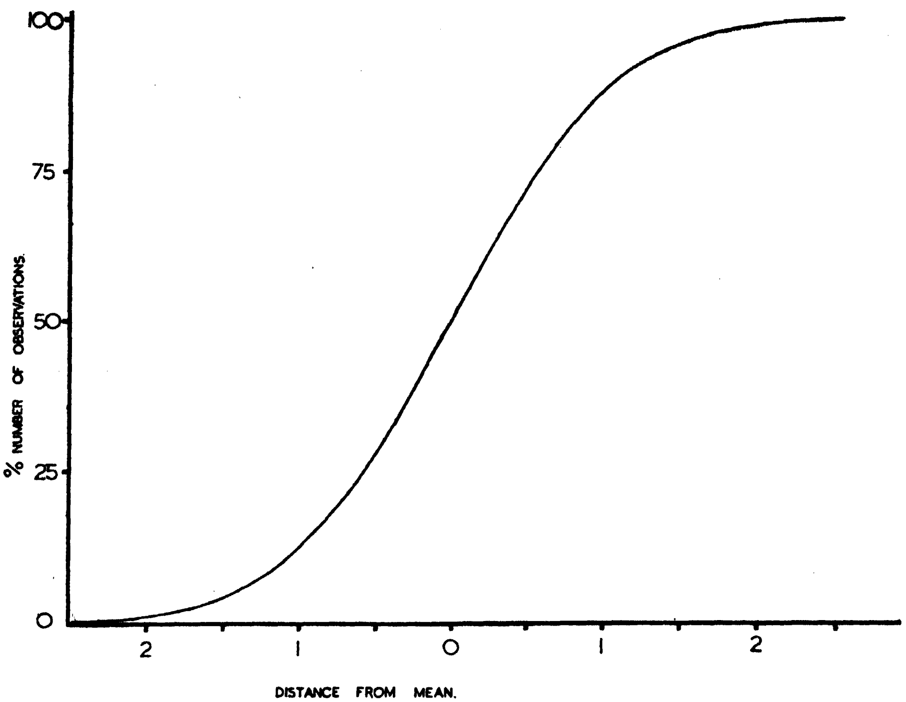


FIG. 1

that value to give an " ogive " curve similar to that shown in Fig. 1. For a normal frequency distribution the shape of the " ogive " curve is given by

$$\frac{n_x}{N}=\frac{1}{\sqrt{2\pi}}\cdot\frac{1}{\sigma}\int_0^x e^{-(x-x_0)^2/2\sigma^2}dx$$

where n_x is the number of observations with values less than x.
N is the total number of observations.
σ is the standard deviation.
x_0 is the mean of the observations.

Galton showed that the median, and the quartiles may be read directly from the curve by reading the intercepts of the curve for $\frac{n_x}{N}=0{\cdot}50$, and $\frac{n_x}{N}=0{\cdot}25$ and $0{\cdot}75$ respectively, whilst Holcomb and Froman pointed out that when

$$\frac{x-x_0}{\sigma}=\pm 0{\cdot}5\,;\quad \frac{n_x}{N}=0{\cdot}3082 \text{ and } 0{\cdot}6918$$

$$\frac{x-x_0}{\sigma}=\pm 1{\cdot}0\,;\quad \frac{n_x}{N}=0{\cdot}1587 \text{ and } 0{\cdot}8413$$

$$\frac{x-x_0}{\sigma}=\pm 1{\cdot}5;\quad \frac{n_x}{N}=0{\cdot}0668 \text{ and } 0{\cdot}9332$$

Consequently the standard deviation may be read directly from the intercepts on the curve at these points.

Hazen and Whipple[3] showed that the "ogive" curve may be projected into a straight line by plotting it on the so-called "probability" graph paper[4] designed for this purpose. When a normal frequency distribution is plotted on this paper the results lie on a straight line and it can be seen from the above that the slope of the straight line will be inversely proportional to the standard deviation. Provided that the frequency distribution is assumed to be normal, it may be completely determined within the limits of experimental error, from two observations. All that is required to construct the straight line on the probability graph paper is the percentage number of observations having values less than two given values. These provide two points through which the straight line may be drawn.

The method of Hazen and Whipple is generally used to check the normality of frequency distributions by testing the degree to which the observed points fit a straight line.

Actually it appears that when the curve is skew the straight line obtained from two or three values of n_x represents a normal distribution fitted to the results at the appropriate values of x. Consequently the median obtained from the straight line as being the value of x when $n_x = \frac{N}{2}$ does not agree with the actual median but lies between it and the mean. For cases in which the skewness is only slight it is generally sufficiently accurate to take the median obtained from the curve as being equal to the mean.

For many purposes, especially in results of measurements upon textiles the variation is expressed as the "coefficient of variation," being equal to the standard deviation expressed as a percentage of the mean. Although the coefficient of variation has little theoretical significance it serves as a useful measure of the irregularity of the sample, for comparison with other samples, having different means.

Graphical Method.

The abbreviated method of obtaining the standard deviation indicated above is as follows. The percentage number of observations having values less than two or more values of x are obtained from the results. These points are plotted upon the probability graph paper and a straight line is drawn through them. The intercepts of the line on the x axis when $\frac{100n_x}{N} = 84{\cdot}13$ and 15·87 are read off from the graph and the difference between the two values of x gives twice the standard deviation. The median is read off from the graph when $\frac{100n_x}{N} = 50$.

When the curve is skew the value of the median obtained by the above method is not equal to the actual median of the frequency distribution but lies between it and mean.

To obtain the coefficient of variation, where this is required, it is generally a sufficiently close approximation to take it as being the standard deviation divided by the median as read from the curve.

Comparison with Root Mean Square Standard Deviation.

The method has been tried out upon results of measurement of the variation in weight along flax slivers (*i.e.*, continuous ribbon of fibres).

Fig. 2 shows a typical frequency distribution for variations of weight

along a flax sliver plotted upon probability paper. As can be seen the points fit well along a straight line showing that the distribution is closely normal. In a large number of trials very good agreement has been found between the standard deviations of the sliver weight obtained from calculation of the root mean square deviation and by the method described here, provided that the two selected values have $\frac{100n_x}{N}$ lying between 10 and 90 per cent.

The results of a number of measurements on different slivers are drawn graphically in Fig. 3, in which the root mean square standard deviation is

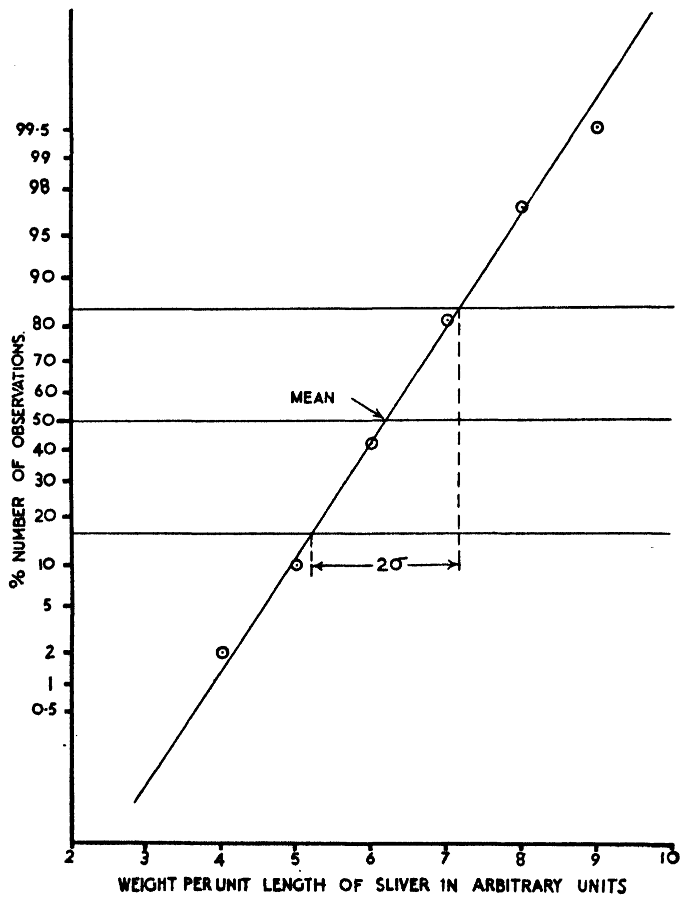


FIG. 2

plotted against the value obtained by the present method using two counters set within the limits prescribed above. The probable error of the results using this method is found to be 3·4 per cent. which is sufficiently close for most purposes.

The probable error of the mean when taken as being the median as calculated by the present method for the present results is found to be 2·5 per cent.

Application of the Method to Integrators operated by Testing Machines.

A number of mechanical integrators have been designed to calculate the mean and standard deviation of the results of routine tests. Most of

these are of a complicated nature and fitting them to a testing machine is frequently a costly operation. Most of them require to be set to an approximate value of the mean and their accuracy may be poor if the difference between the setting and the actual mean is too large. The calculator invented by Matthew and Keig[5] falls into this class. This is designed for attachment to a strength testing machine and calculates the standard deviation via the mean deviation.

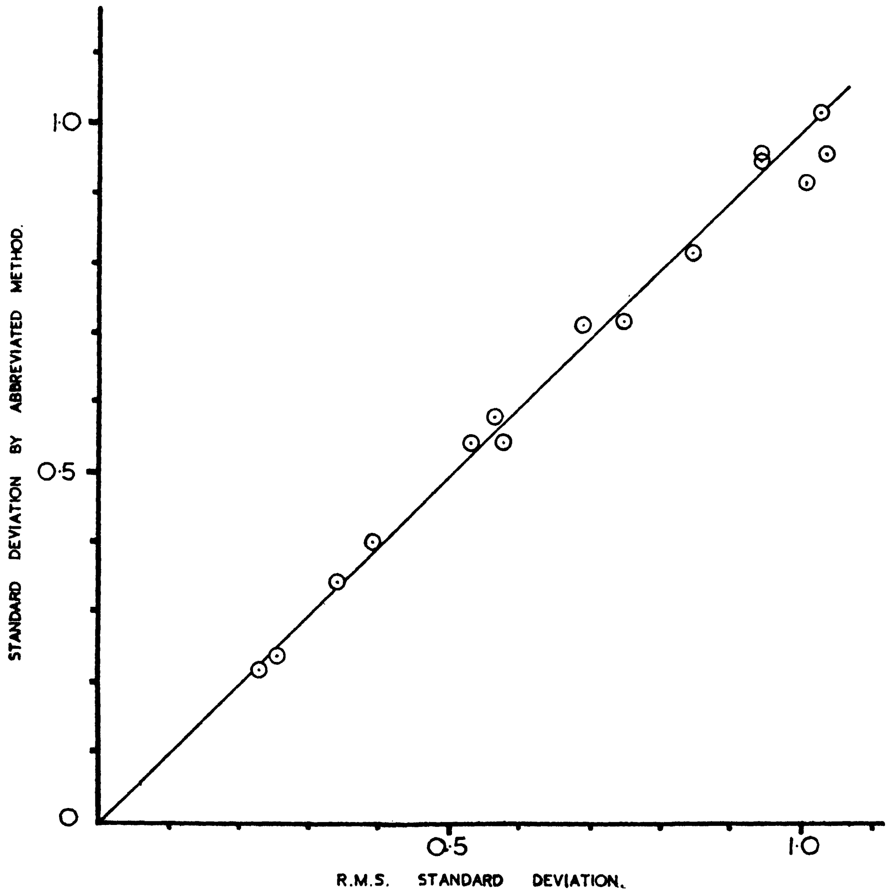


FIG. 3

Several machines that calculate the mean square deviation have been described by Foster[6]; these overcome the above disadvantages to a large extent but they are necessarily more complicated than the simple apparatus suggested below.

The method described above can readily be adapted to form an attachment to testing machines, by which the number of observations less than two selected values can be obtained mechanically. These are used for the graphical treatment described above.

It is only necessary to arrange two or more counters at pre-selected values so that they would be operated by the testing machine when these values of the quantity being measured are exceeded in the various tests. It should be pointed out that when only two counters are used there is a risk

that if a sample occurs with a frequency distribution far from normal, a serious error may result. For accuracy the two pre-selected values should be on either side of the mean.

The exact form of mounting would vary with the testing machine, but in all cases provision would need to be made for varying the position of the counters relative to the machine scale. The counters would be mounted on this scale and operated by the indicator of the machine or two or more counters could be adjustably mounted on the moving part of the machine and be operated by a fixed stop on the scale. In cases where the friction of the counters is undesirable they could be worked by means of relays working from electrical contacts.

It appears likely that different types of mounting would be required to suit the requirements of different types of testing machines, so no attempt is made to describe any particular attachment.

This method appears to be particularly suitable for attachment to a recording drum on which a varying quantity is being continuously or intermittently recorded, to render the calculation of the variability very simple and rapid.

In conclusion we wish to thank the Council of the Linen Industry Research Association for permission to publish these results.

REFERENCES

[1] H. Holcombe and D. K. Froman. *Can. J. Res.*, D, 1936, **14**, p. 15.
[2] Sir Francis Galton. *Phil. Mag.*, 1875, **49**, (4), p. 33.
[3] Arithmetic Probability Paper. designed by Hazen, Whipple and Fuller, Codex Book Co., Inc., New York, U.S.A.
[4] Manufactured by Messrs. Wightman Mountain, Ltd., Artillery House, Artillery Row, Westminster, S.W.1.
[5] Linen Industry Research Association, J. A. Matthew and R. J. B. Keig. E.P.409,006 of 1932-34.
[6] G. A. R. Foster. *J. Text. Inst.*, 1936, **27**, T37.

Received 7/12/36.

4.—THE DISSOLUTION OF CHEMICALLY MODIFIED COTTON CELLULOSE IN ALKALINE SOLUTIONS

PART 3—IN SOLUTIONS OF SODIUM AND POTASSIUM HYDROXIDE CONTAINING DISSOLVED ZINC, BERYLLIUM AND ALUMINIUM OXIDES

BY

G. F. DAVIDSON, D.Sc.

(British Cotton Industry Research Association)

I. INTRODUCTION AND SUMMARY.

John Mercer observed that by dissolving zinc oxide in sodium hydroxide solution the swelling action of the solution on cotton was increased,[9] and in 1889 the use of such a solution to produce certain of the effects of mercerisation was included in a patent by Lowe.[7] Recently, Lewis[6] has described the use of a solution of sodium hydroxide containing dissolved zinc oxide as a swelling agent for the detection of chemically damaged cotton by microscopical examination. In Parts I and II of this series[2,3] it has been shown that there is a close relation between the swelling of cellulose in solutions of strong bases and the solubility (percentage dissolved under standardised conditions) of chemically modified cotton cellulose in similar solutions, and it would thus be expected that the enhanced swelling action of solutions of sodium hydroxide containing dissolved zinc oxide would be accompanied by enhanced solvent action on modified cottons. The solvent action of such solutions of zinc oxide was therefore examined, and when the expected results were found, the investigation was extended to include two other amphoteric oxides—the oxides of beryllium and aluminium. In view of the differences in behaviour previously found between solutions of potassium hydroxide and of the other strong bases examined,[3] the effect of dissolved zinc oxide on the solvent action of potassium hydroxide solutions was also investigated.

In what follows, the solutions of zinc, beryllium and aluminium oxides in solutions of sodium or potassium hydroxide containing caustic alkali considerably in excess of the amphoteric oxide equivalent, will, for the sake of brevity, be referred to as solutions of zincate, beryllate and aluminate, respectively. Their composition will be defined by (1) the concentration (normality) of the total sodium or potassium hydroxide, free and combined, present in the solution, (2) the molar ratio of amphoteric oxide to sodium or potassium hydroxide.

It has been found that the solvent action of sodium zincate solutions on cotton and modified cotton cellulose, like that of solutions of sodium hydroxide, is a maximum at a certain concentration of caustic alkali and that the maximum solubility of a given material is the greater the higher the molar ratio of zinc oxide to sodium hydroxide in the solutions; as this ratio is increased, the position of the maximum shifts towards higher sodium hydroxide concentrations. Thus, with a certain oxycellulose, when the molar ratio $ZnO/NaOH$ was 0, 0·05, 0·10 and 0·178, the maximum solubilities observed at 15° C. were 10·5, 38·9, 77·5, and 97·3 per cent., and these maxima occurred at sodium hydroxide concentrations of 3·0, 3·0, 3·25 and 3·5N, respectively. The solvent action is greatly increased by lowering the temperature, and by using a temperature of —5° C. and a zincate solution with a high molar ratio of zinc oxide to sodium hydroxide it is possible to dissolve unmodified cotton to a considerable extent; for example, with a cotton of fluidity 4·1 a solubility of 45 per cent. has been attained.

Solubility measurements have been made on modified cottons treated at 15° C. with zincate solution $5N$ in sodium hydroxide and at 0° and —5° C. with $5N$ sodium hydroxide solution containing no zinc oxide, the solutions then being diluted to a range of lower concentrations at the same temperature. The solubility curves thus obtained, when compared with those found by direct extraction, are displaced towards lower alkali concentrations, but the effect on the maximum solubility depends on the conditions. Thus with sodium zincate at 15° C., or with sodium hydroxide alone at 0° C., the maximum solubilities by the dilution method and by direct extraction are nearly the same, whilst with sodium hydroxide alone at —5° C. the dilution method gives a considerably lower maximum solubility than direct extraction.

The relation between the fluidity of a series of cottons and modified cottons in cuprammonium and their solubility in sodium hydroxide and sodium zincate solution at 15° C. and —5° C. has been investigated.

In order to prepare concentrated, stable solutions of modified cottons in sodium zincate solutions, it is necessary to use zincate solutions with a molar ratio of zinc oxide to sodium hydroxide not much above 0·1 and a sodium hydroxide concentration of about $2{\cdot}5N$, and to dissolve the modified cotton at a low temperature. At high sodium hydroxide concentrations, the solutions tend to form gels on standing, and if a high molar ratio ZnO/NaOH is used in a solution $2{\cdot}5N$ in sodium hydroxide, precipitation of zinc oxide takes place.

The presence of dissolved zinc oxide in potassium hydroxide solutions increases the maximum swelling of regenerated cellulose sheet and the solubility of modified celluloses in the solution. The form of the solubility curve obtained with a modified cellulose in potassium zincate solutions is similar to that of the same material in potassium hydroxide solutions; regenerated cellulose sheet and an oxycellulose prepared from cotton swollen prior to modification give curves with a single maximum, while oxycelluloses prepared from unmercerised cotton give curves with two maxima. For a given molar ratio of zinc oxide to caustic alkali, potassium zincate solutions are much less effective solvents for modified celluloses than sodium zincate solutions.

Solutions of sodium beryllate have a greater solvent action than solutions of sodium hydroxide, and in other respects also behave like solutions of sodium zincate; their solvent action is, however, in general, less than that of zincate solutions. On the other hand, the presence of dissolved aluminium oxide in sodium hydroxide solutions has the effect of depressing the solvent action of the solutions.

II. EXPERIMENTAL

(1) Determination of Solubility of Cotton and Modified Cotton.

The methods used for the determination of solubility were similar to those described in Part I of this series,[2] with the slight modifications introduced in Part II.[3]

(2) Materials.

(a) *Cottons and Modified Cottons.* The cottons and modified cottons used were, for the most part, drawn from those described in Part I.[2] They consisted of (1) scoured cottons, (2) a series of oxycelluloses (OL6/B—OL16/B), prepared from scoured cotton linters by the action of sodium hypochlorite solutions of *p*H 8·4, and subjected to an alkaline boil after modification, (3) an oxycellulose CSO3, prepared by oxidation with gaseous oxygen of a scoured cotton impregnated with $10N$ sodium hydroxide

solution. The fluidity of these materials in cuprammonium (0·5 per cent. solution, 20° C.) is given as a measure of their degree of modification, the fluidities of the scoured cottons and the hypochlorite oxycelluloses being included in Table V.

(b) *Preparation and Analysis of Zincate Solutions.* Sodium zincate solutions are readily prepared by shaking anhydrous zinc oxide with concentrated sodium hydroxide solutions; the solubility relations in this system have been investigated by Goudriaan[5] and Müller.[8] Sodium zincate solutions of known composition were prepared by shaking together weighed quantities of pure zinc oxide and 40 per cent. sodium hydroxide solution, and these were then diluted with water to give a series of solutions with a constant molar ratio of zinc oxide to sodium hydroxide, but with various concentrations of total sodium hydroxide. The highest molar ratio reached was 0·229; this was attained by shaking a 40 per cent. solution of sodium hydroxide with excess of zinc oxide for 24 hours, heating the suspension to boiling, and allowing it to cool. After standing for several days, the solution was separated from the undissolved zinc oxide by centrifuging in stoppered tubes.

Where it was necessary to analyse sodium zincate solutions, the sodium hydroxide was determined by titration with normal hydrochloric acid, and the zinc oxide by precipitation from an acidified solution as basic carbonate, igniting, and weighing as oxide. The validity of the titration method was tested by the titration of solutions of known composition, prepared as described above. Weighed quantities of these solutions were titrated to the phenolphthalein and methyl red end-points, the results being given in Table I.

They show that if the titration to the phenolphthalein end-point is taken as giving the sodium hydroxide concentration, the result is about 0·5 per cent.

Table I
Analyses of Sodium Zincate Solutions
(Milli-equivalents per gm. solution)

	Sodium hydroxide (phenolphthalein)		Total base (methyl red)	
Calculated	8·70	8·97	11·84	11·53
Found	8·75, 8·75, 8·74, 8·75	9·02, 9·01	11·83, 11·83	11·53, 11·54

too high; this is contrary to the findings of Fricke and Humme,[4] who state that too low results are obtained. Titration to the methyl red end-point, which corresponds closely with the re-dissolution of the zinc oxide, gives accurately the concentration of total base, i.e. sodium hydroxide and zinc oxide. The sodium hydroxide concentration is thus more accurately obtained from this result and the gravimetric determination of zinc oxide, but for the purposes of the present work the result obtained by the more rapid titration to the phenolphthalein end-point is sufficiently accurate.

Many of the sodium zincate solutions used were super-saturated, and from those with the highest molar ratios of ZnO/NaOH and the lowest sodium hydroxide concentrations used, a precipitate, which was sometimes crystalline, separated slowly. Solutions were usually prepared immediately before use by dilution of stable stock solutions 5*N* or 6*N* in sodium hydroxide, and only in a few instances was there any precipitation of zinc oxide during the actual measurements of the solubility of modified cellulose.

Zinc oxide is less soluble in potassium hydroxide than in sodium hydroxide solutions,[8] and the highest molar ratio of zinc oxide to potassium hydroxide attained by shaking the anhydrous oxide with 45 per cent. potassium hydroxide solution and then heating the suspension was 0·143. The solutions of potassium zincate employed in solubility measurements had a molar ratio ZnO/KOH of 0·14.

(c) *Preparation and Analysis of Beryllate Solutions.* Unlike zinc oxide, anhydrous beryllium oxide does not dissolve in sodium hydroxide solutions. A preliminary preparation was made by dissolving hydrous beryllium oxide—precipitated from a solution of the chloride with ammonia, washed and partially dehydrated over phosphorus pentoxide—in concentrated sodium hydroxide solution, but most of the work was done with solutions prepared by dissolving metallic beryllium (98 per cent. pure, in the form of flakes) in 35 per cent. sodium hydroxide solution. The solution was freed from the undissolved residue by centrifuging in stoppered tubes. The solutions were analysed by determining the total sodium hydroxide by titration with standard acid to the phenolphthalein end-point, and the beryllium by precipitation from an acid solution with ammonia, washing with a 2 per cent. solution of ammonium acetate containing ammonia, igniting and weighing as oxide.

The highest molar ratio of beryllium oxide to sodium hydroxide used in measurements of the solubility of modified cottons was 0·274 but even solutions 6*N* in sodium hydroxide were unstable ; it was possible to use this molar ratio by centrifuging the stock solution before use and analysing the clear solution used. With molar ratios of 0·2 and 0·1, the solutions were as stable as the zincate solutions.

(d) *Preparation and Analysis of Aluminate Solutions.* Sodium aluminate solutions were prepared by dissolving aluminium turnings in 40 per cent. sodium hydroxide solution, and separated from insoluble matter by centrifuging. The sodium hydroxide concentration was determined by titration with standard acid to the phenolphthalein end-point, and the aluminium gravimetrically as oxide. No precipitation of alumina from any of the aluminate solutions used was observed, but when stock solutions were diluted to a low sodium hydroxide concentration there was a slight precipitation of ferric oxide on standing. It should be noticed that in an aluminate solution a given molar ratio of oxide to sodium hydroxide corresponds to double the atomic ratio of metal to sodium that would be given by the same molar ratio in a zincate or beryllate solution.

(3) The Solvent Action of Sodium Zincate Solutions.

The solvent action of sodium zincate solutions at 15° C. was investigated by determining the solubility of the oxycellulose OL7/B (fluidity, 34·1) in solutions of various sodium hydroxide concentrations and with various molar ratios of zinc oxide to sodium hydroxide. The results obtained are given in Table II and Fig. 1. They show that at low sodium hydroxide

Table II
Solubility of Oxycellulose OL7/B in Sodium Zincate Solutions at 15°C.

ZnO/NaOH (moles)	Percentage dissolved											
	Concentration of sodium hydroxide (normality)											
	2·00	2·25	2·50	2·75	3·00	3·25	3·50	3·75	4·00	4·50	5·00	6·00
0	1·4	2·5	4·4	7·8	10·5	8·6	6·3	—	3·4	—	1·7	—
0·050	1·3	—	4·3	18·8	38·9	33·7	20·7	13·1	8·5	4·3	3·5	—
0·100	1·6	—	5·0	21·0	50·9	77·5	66·2	40·8	26·0	10·2	5·9	—
0·178	1·2	—	3·9	17·2	49·5	87·7	97·3	90·2	57·3	27·3	10·3	3·2

concentrations the presence of dissolved zinc oxide has little effect on the solubility of the oxycellulose, but when the sodium hydroxide concentration reaches about 2·75*N* the solubility in the zincate solutions begins to rise rapidly. The solubility goes through a maximum when the sodium hydroxide concentration is further increased, and this maximum is the higher the

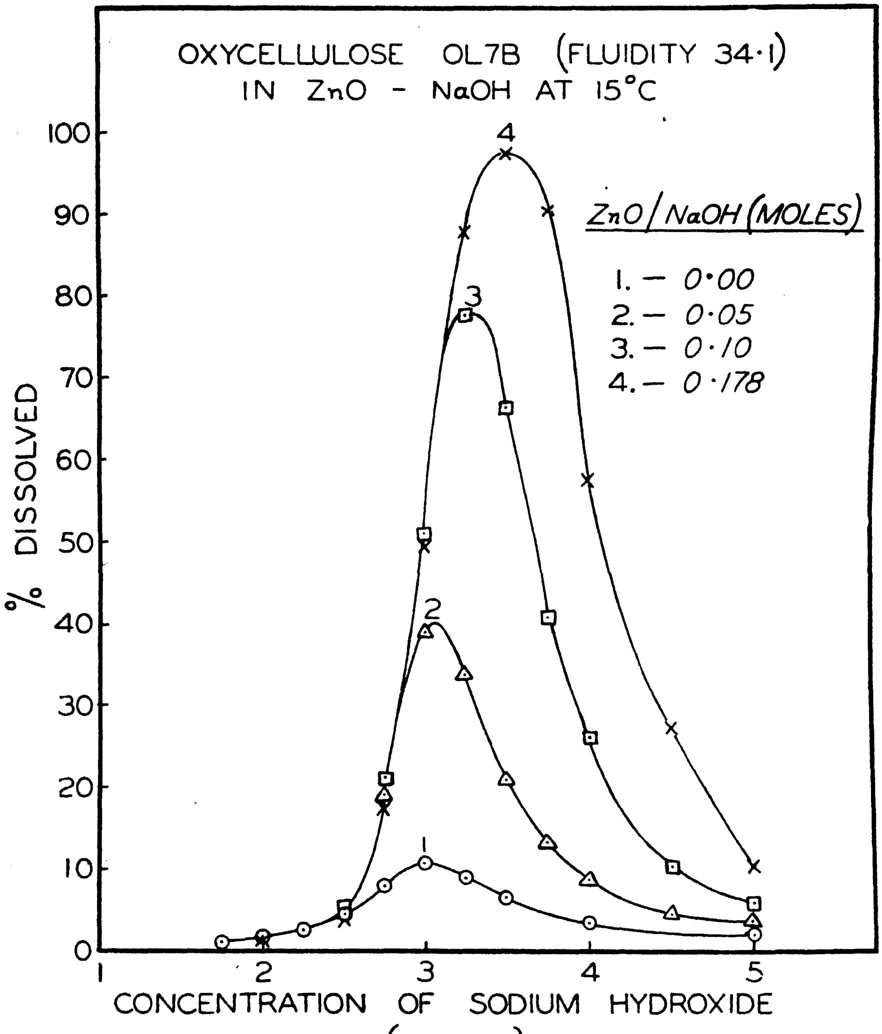


Fig. 1.

greater the molar ratio of zinc oxide to sodium hydroxide. As the molar ratio is increased, the maximum shifts towards higher sodium hydroxide concentrations.

As the oxycellulose OL7/B was practically completely soluble in sodium zincate solution 3·5*N* in sodium hydroxide and having a molar ratio ZnO/NaOH of 0·178, it was necessary to use a less highly modified cotton to investigate the effect of low temperatures with zincate solutions. For this purpose the oxycellulose OL14/B (fluidity 16·1) was employed. Table III

gives the results of solubility measurements at 15° and —5° C. with this material in zincate solutions with molar ratios ZnO/NaOH of 0·10 and 0·178. The results show that, as with sodium hydroxide solutions,[8] lowering

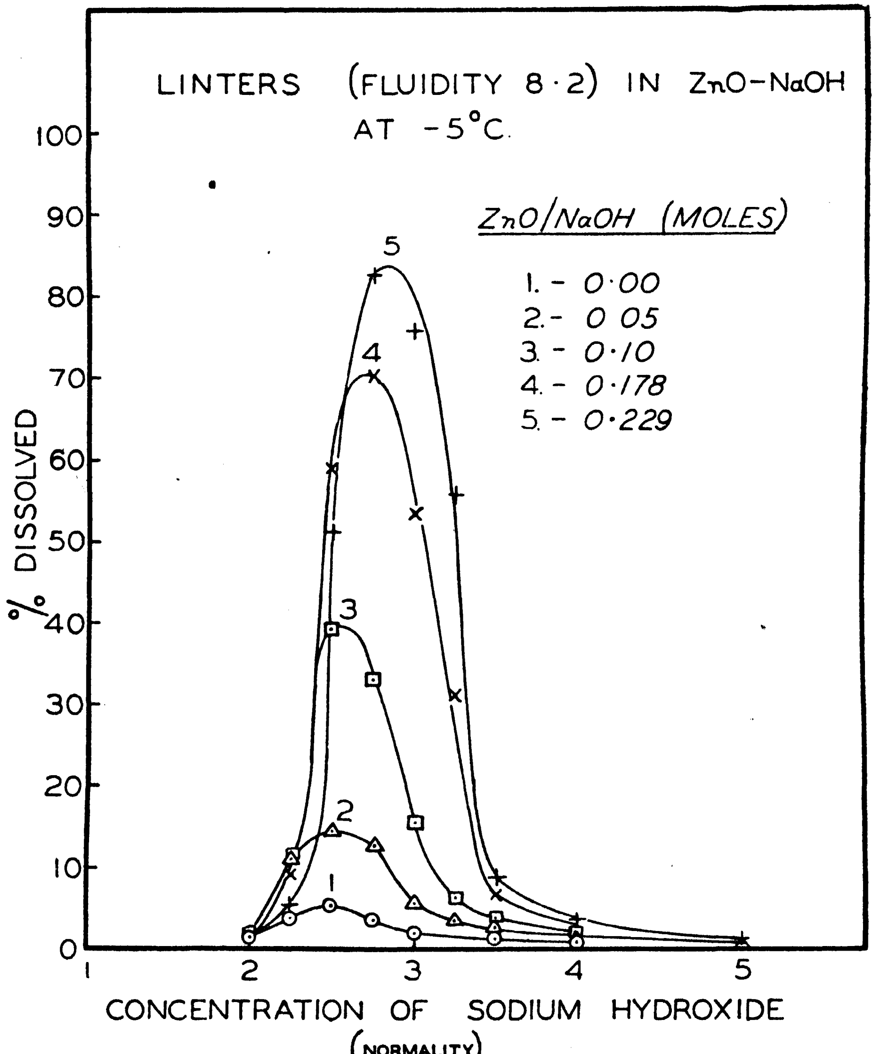


Fig. 2.

Table III
Effect of Temperature on Solubility

ZnO/NaOH (moles)	Temp. (° C.)	Percentage dissolved — Concentration of sodium hydroxide (normality at 18° C.)									
		2·00	2·25	2·50	2·75	3·00	3·25	3·50	3·75	4·00	5·00
0·100	15	—	—	1·4	—	6·2	11·6	8·8	6·1	3·6	1·3
0·100	−5	3·2	36·9	82·4	84·9	72·2	53·4	24·8	—	6·1	2·3
0·178	15	—	—	1·3	—	4·6	25·4	40·1	25·5	12·6	2·6
0·178	−5	1·9	26·8	80·5	93·6	94·2	87·7	63·5	38·2	13·0	2·9

the temperature to —5° C. produces a great increase in the maximum solubility, and shifts the maximum to a lower sodium hydroxide concentration.

The effect of the molar ratio ZnO/NaOH on the solvent action of zincate solutions at —5° C. was investigated in greater detail with scoured linters No. 310 (fluidity 8·2) and the results are given in Table IV and Fig. 2. The terms "unmodified cotton" and "modified cotton" are purely relative, but this material would, for textile purposes, be regarded as an unmodified

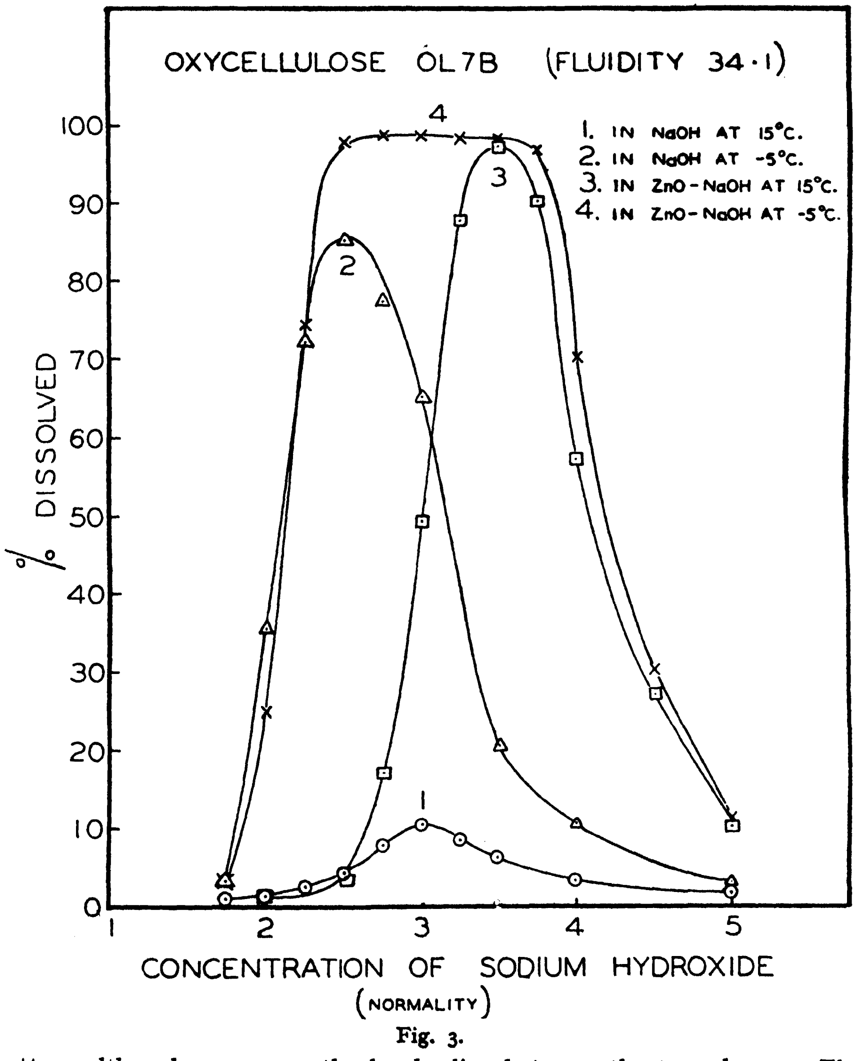


Fig. 3.

cotton, although very near the border-line between the two classes. The results show that, as at 15° C., the maximum solubility increases with increasing molar ratio ZnO/NaOH, while at the same time this maximum solubility occurs at progressively higher sodium hydroxide concentrations. The crossing of the solubility curves at low sodium hydroxide concentrations shows that here increasing zinc oxide concentration eventually lowers the solubility, and this is also shown, although to a less extent, by the results

already given for 15° C. (Table II). The striking feature of the results at —5° C. is that by using a zincate solution with a high ZnO/NaOH ratio, a cotton of fluidity 8·2 may be brought into solution to the extent of 82 per

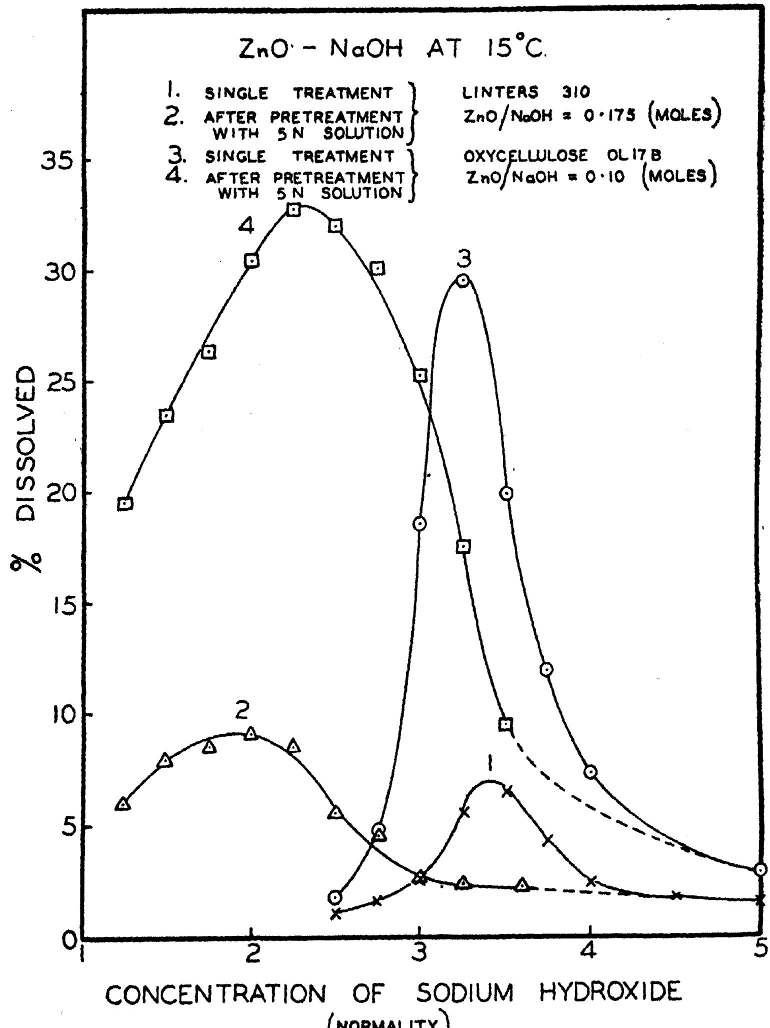


Fig. 4.

Table IV

Solubility of Linters No. 310 in Sodium Zincate at —5° C.

ZnO/NaOH (moles)	Percentage dissolved								
	Concentration of sodium hydroxide (normality at 18° C.)								
	2·00	2·25	2·50	2·75	3·00	3·25	3·50	4·00	5·00
0	1·3	3·8	5·2	3·5	1·9	—	1·1	0·5	—
0·050	1·9	10·1	14·5	12·6	5·5	3·3	2·3	0·8	0·3
0·100	2·0	11·2	39·2	33·0	15·5	6·2	3·6	1·5	—
0·178	1·4	9·1	58·4	70·1	53·3	31·0	6·9	2·5	—
0·229	1·4	5·3	51·2	82·6	75·6	55·6	8·7	3·5	1·0

cent. By lowering the temperature to —10° C. and using a solution with a molar ratio ZnO/NaOH of 0·229 and a sodium hydroxide concentration of 2·75*N*, this figure was increased to 89 per cent.

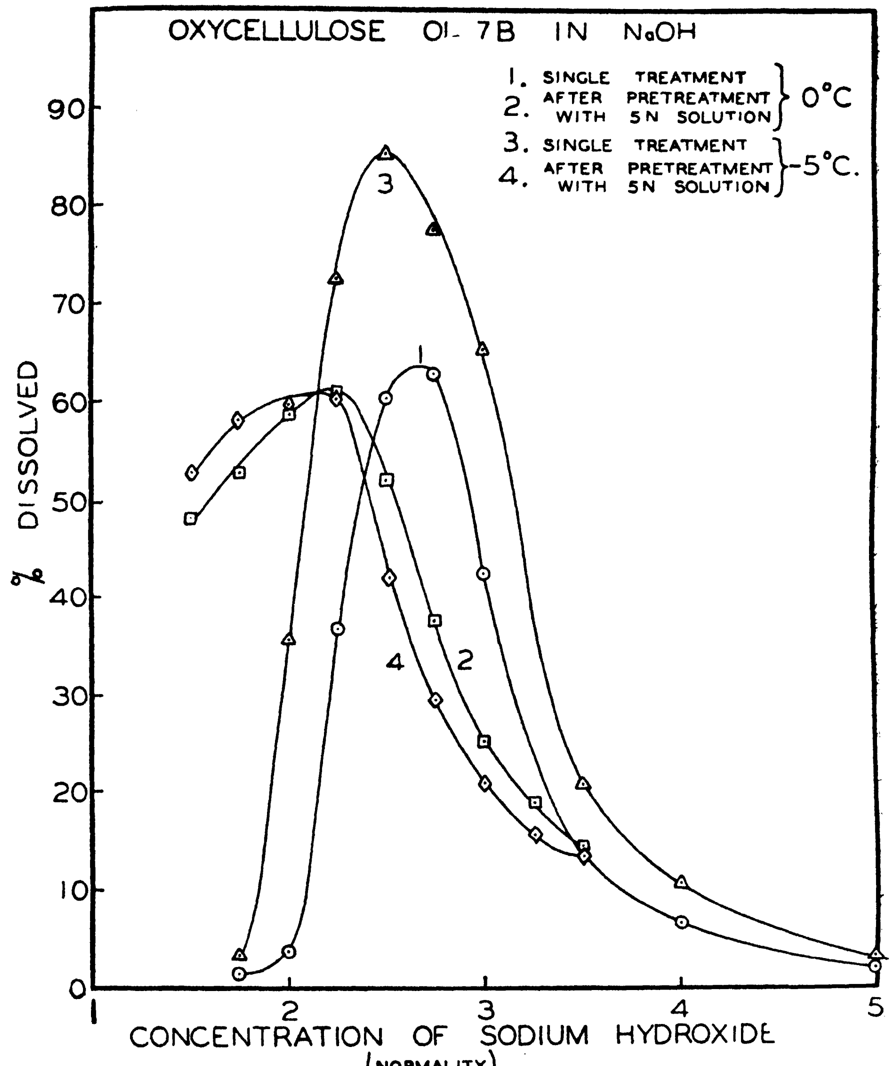


Fig. 5.

The solubility of the oxycellulose OL7/B in sodium hydroxide solutions at 15° C. and —5° C. has already been given in Part I,[2] and by using these data and solubility determinations in zincate solutions at the same temperatures, the separate and combined effects of low temperature and dissolved zinc oxide can be well illustrated. This is done in Fig. 3; the solubility data for zincate solutions refer to solutions with a molar ratio ZnO/NaOH of 0·178. Figure 3 shows that the effects of the two factors are superimposed, with the result that at —5° C. the oxycellulose is practically completely soluble in zincate solutions over a sodium hydroxide concentration range of from 2·5*N* to 3·75*N*.

(4) The Solubility of Cottons and Modified Cottons after Pre-treatment with 5N Sodium Hydroxide Solution, and with Zincate Solution 5N in Sodium Hydroxide, followed by Dilution to Lower Concentrations.

Birtwell, Clibbens and Geake[1] found that by treating a modified cotton at 15° C. with sodium hydroxide solutions from 5 to 10*N* and then diluting the alkali to various lower concentrations a maximum solubility was obtained that was greater than that found in a single solution of any concentration. It was therefore of interest to examine the behaviour of sodium zincate solutions in this respect. Half a gram of cotton or modified cotton was treated at 15°C with x cc. of a zincate solution 5*N* in sodium hydroxide and the solution then rapidly diluted with (50—x) cc. of water at 15° C., thus obtaining a series of final sodium hydroxide concentrations. This was done with the linters No. 310, a zincate solution with a molar ratio ZnO/NaOH of 0·175 being used, and with an oxycellulose OL17/B (fluidity 23·1) at a molar ratio of 0·10. The results are shown graphically in Fig. 4, and are compared with the solubilities measured in solutions of various concentrations without pre-treatment with 5*N* solution.

The most general feature of the solubility curve obtained by the dilution method is that, by comparison with results obtained in extraction at constant concentration, the whole curve is displaced in the direction of lower alkali concentrations. This displacement is immediately obvious in its effect on the position of the maximum. Thus, Fig. 4 shows that with sodium zincate solutions at 15° C. the position of the maximum is displaced from the

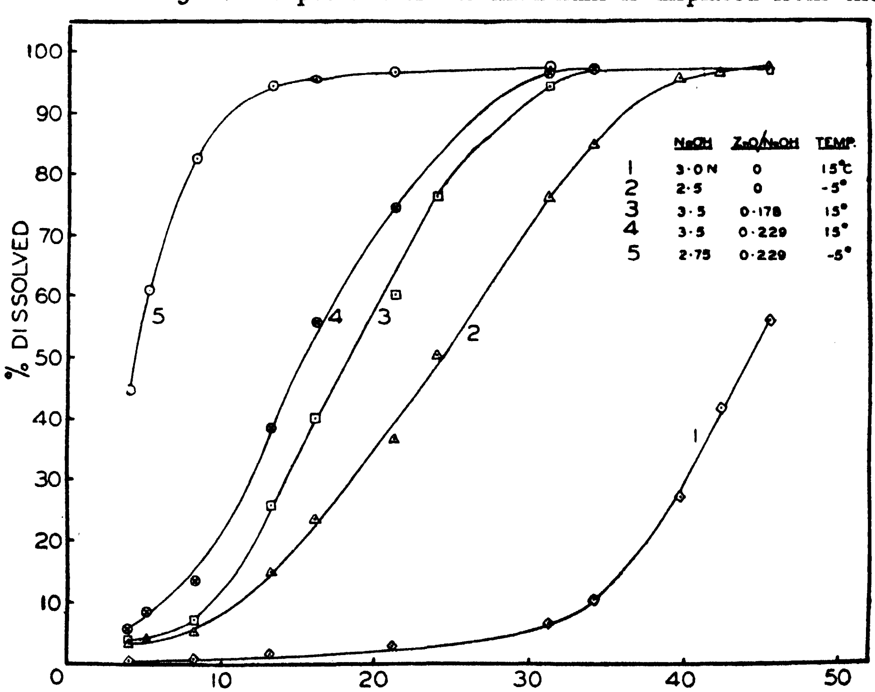


Fig. 6.

neighbourhood of 3·25*N* (direct extraction) to that of 2*N* (dilution), and a similar displacement was observed in the earlier work[1, 2] with solutions of sodium hydroxide at 15° C. A previous paper[2] included a few isolated measurements of the solubility of modified cottons in sodium hydroxide

solutions by the dilution method at 0° and —5° C., and, in the hope of arriving at a more systematic classification of the results obtained by the dilution method under a variety of conditions, these measurements have now been extended to include a series of final concentrations.

Experiments were made in which 0·5 gm. of the oxycellulose OL7/B was added to x cc. of 5N sodium hydroxide solution, the mixture cooled to 0° or —5° C., and then diluted by the rapid addition of (50—x) cc. of water at 0·5° C.; the mixture was then shaken and again cooled to 0° or —5° C.; the results are compared in Fig. 5 with those obtained by direct extraction with single solutions at these temperatures.

At both temperatures the maximum occurs at a lower alkali concentration in the dilution method than in the direct extraction, so that the rule found to hold for sodium hydroxide and sodium zincate solutions at 15° C. also applies here. The effect on the maximum solubility, however, varies greatly with the conditions. With sodium hydroxide solutions at 15° C. a much greater maximum solubility is realised by the dilution method than by direct extraction.[1,2] With zincate solutions at 15° C. and with sodium hydroxide solutions at 0° C. the maximum solubility is not very different by the two methods; whilst with sodium hydroxide solutions at —5° C. the dilution method gives a much lower maximum solubility than the direct extraction method.

(5) The Relation between the Fluidity of Cotton Materials and their Solubility in Sodium Hydroxide and Sodium Zincate Solutions.

In Part I of this series[2] the relation between the fluidity and the solubility in 2·5N sodium hydroxide solution at —5° C. was given for a series of hypochlorite oxycelluloses. The solubilities of the same series of oxycelluloses, supplemented by a few scoured cottons of low fluidity, were determined in sodium hydroxide solution at 15° C. and in sodium zincate solutions at 15° C. and —5° C. at the sodium hydroxide concentration that gives maximum solubility. The results are given in Table V, and the relations between fluidity and solubility are shown graphically in Fig. 6.

Table V
Fluidity and Solubility Relationships

Material	Fluidity	Percentage dissolved				
		15° C.			-5° C.	
		NaOH, 3·0N	Zincate. NaOH, 3·5N ZnO/NaOH = 0·178	Zincate. NaOH, 3·5N ZnO/NaOH = 0·229	NaOH, 2·5N	Zincate. NaOH, 2·75N ZnO/NaOH = 0·229
Scoured cotton						
103R	4·1	0·6	3·7	5·6	3·4	44·9
85R	5·2	—	—	8·6	4·2	60·9
310	8·2	0·9	7·2	13·7	5·2	82·6
Oxycellulose						
OL13/B	13·2	1·7	25·7	38·6	15·0	94·5
OL14/B	16·1	—	40·1	55·8	23·5	96·0
OL15/B	21·2	2·8	60·2	74·7	36·7	97·2
OL16/B	23·9	—	76·5	—	50·5	—
OL11/B	31·2	6·7	94·6	96·6	76·4	97·6
OL7/B	34·1	10·5	97·3	97·4	85·2	—
OL12/B	39·7	27·2	—	—	95·7	—
OL9/B	42·3	41·9	—	—	96·8	—
OL6/B	45·4	57·6	97·4	—	97·6	—

The powerful solvent action of zincate solutions at —5° C. is shown by the fact that cotton No. 103R, a material more typical of unmodified cotton than No. 310, can be dissolved to the extent of 45 per cent. Fig. 6 suggests that, as a measure of chemical degradation of cellulose, solubility in zincate solution at 15° C. is much more suitable than solubility in sodium hydroxide solution at that temperature, since the former measurement is much more sensitive than the latter in the region of slight chemical attack.

(6) The Stability of Concentrated Solutions of Modified Cellulose in Sodium Zincate Solutions.

Concentrated solutions of modified cellulose were prepared by utilising the solvent action of sodium zincate solutions, and the stability of the solutions studied in a qualitative way. The behaviour of such solutions on standing at the room temperature may be illustrated by means of the results obtained with the oxycellulose OL7/B (Table VI). It has already been seen that the optimum conditions for dissolving modified cottons at 15° C. are a high molar ratio of zinc oxide to sodium hydroxide and a sodium hydroxide concentration of $3{\cdot}5N$, but the results given in Table VI show that such conditions are unsuitable for preparing concentrated solutions of modified cellulose, since even a 3 per cent. solution of a material of fluidity 34, prepared under such conditions, soon forms a gel. In order to prevent gel formation, it is necessary to reduce the sodium hydroxide concentration, and since this reduces the solvent action at 15° C. it becomes necessary to employ low temperatures for the preparation of the solutions. Table VI also shows that if the molar ratio ZnO/NaOH is high, reduction of the sodium hydroxide concentration tends to produce precipitation of zinc oxide. This necessitates lowering the molar ratio ZnO/NaOH, again at the expense of solvent power. However, as the Table shows, it is possible to produce 5 per cent. solutions of a modified cotton of fluidity 34, stable both with respect to gel formation and precipitation of zinc oxide, by dissolving the material at temperatures of from —5° to —10° C. in zincate solutions $2{\cdot}5N$ or $2{\cdot}75N$ in sodium hydroxide and having a molar ratio ZnO/NaOH of 0·1. From such solutions strong, thin films were prepared by coating a glass plate with a thin layer of the solution and immersing it in an acid solution.

(7) The Solvent Action of Potassium Zincate Solutions.

It was shown in Part II[8] that the solvent action of solutions of potassium hydroxide on modified celluloses is very much less than that of solutions of the other strong bases examined, and that with modified celluloses prepared from unmercerised cotton the curves relating solubility and potassium hydroxide concentration have two maxima. It was therefore of interest to investigate the effect of the presence of dissolved zinc oxide in the potassium hydroxide solutions. The solubility of the oxycellulose OL6/B was measured in potassium zincate solutions with a molar ratio ZnO/KOH of 0·14 under the conditions previously used in measurements with potassium hydroxide solutions, viz. (1) at 15° C., (2) at —5° C., adding the oxycellulose to the solution at 15° C., (3) at —5° C., cooling the solution to that temperature before adding the oxycellulose. The results obtained are recorded in Table VII, and in Fig. 7 they are compared with those found at 15° C. in sodium zincate solutions with the same molar ratio of zinc oxide to caustic alkali. Comparison with the results previously found with potassium hydroxide solutions[8] shows that the presence of dissolved zinc oxide increases the solvent action and renders the two maxima in the solubility curves more

Table VI

Preparation of Concentrated Solutions of Modified Cellulose

ZnO/NaOH (moles)	Concentration of modified cellulose (%)	Concentration of NaOH in zincate solution (normality)	Temperature of preparation of solution (° C.)	Remarks.
0·200	3	2·5	−10	Fluid after 8 days; precipitate of zinc oxide formed.
		2·75	−5	
		3·0	−5	Gelled in 48 hours.
		3·25	0	Gelled in 2½ hours.
		3·5	15	Gelled in ½-hour.
	5	2·5	−9 (frozen)	Fluid after 8 days; precipitate of ZnO formed.
		2·75	−5	Gelled in 5 days.
		3·0	−5	Gelled in 5 hours.
	7	2·5	−9 (frozen)	Fluid after 7 days; precipitate of ZnO formed.
		2·75	−5	Gelled in 96 hours.
		3·0	−5	Gelled in 2½ hours.
0·178	5	2·5	−10	Fluid after 15 days; precipitate of ZnO formed.
		2·75	−5	Fluid after 15 days; slight precipitate of ZnO.
		3·0	−5	Gelled in 1 hour.
		3·25	−5	Practically dissolved at 5° C.; gelled at −5° C.
	7	2·5	−9 (frozen)	Fluid after 14 days, gelled later; slight precipitate of ZnO.
		2·75	−5	Gelled in 3 days.
		3·0	−5	Gelled on reverting to room temperature.
		3·25	−5	Gelled immediately.
0·100	5	2·5	−10	Fluid after 7 days; no precipitate of zinc oxide.
		2·75	−5	
		3·0	−5	Gelled in ½-hour.
	7	2·5	−10	Gelled in 3 days.
		2·75	−5	Gelled in 1 hour.

pronounced ; it also makes the maxima occur at higher alkali concentrations, although the effect on the position of the first maximum in each curve is not great. The effect of variation of the temperature at which the modified cotton is added to the alkali solution prior to extraction at —5° C. is even greater with potassium zincate than with potassium hydroxide solutions ; when the addition is made at —5° C. instead of at 15° C. the first maximum is increased from 25 per cent. to 71 per cent. Fig. 7 also shows that, as was found with the hydroxides, potassium zincate solutions are much inferior to sodium zincate solutions as solvents for modified cotton.

In Part II[8] it was found that regenerated cellulose sheet and modified celluloses prepared from cotton previously swollen with concentrated sodium

Table VII
Solubility in Potassium Zincate Solutions

Concentration of potassium hydroxide (normality at 18° C.)	Percentage dissolved				
	Oxycellulose OL6/B			Oxycellulose OL7/B	Oxycellulose CSO3
	15° C.	− 5°C, adding oxycellulose to solution at 15° C.	− 5°C, adding oxycellulose to solution at − 5° C.	− 5°C, adding oxycellulose to solution at − 5° C.	− 5°C, adding oxycellulose to solution at − 5° C.
1·75	4·2	10·1	25·4	2·1	2·2
2·00	5·7	16·5	57·1	5·6	3·3
2·25	8·4	23·2	70·8	10·0	—
2·50	12·4	24·8	60·8	9·0	6·5
2·75	16·9	24·4	50·5	6·8	—
3·00	18·6	21·1	39·2	5·8	10·7
3·25	16·6	18·4	33·2	5·4	—
3·50	14·3	15·6	30·1	5·9	15·2
3·75	—	15·3	29·6	—	18·2
4·00	12·2	16·3	30·3	7·1	22·7
4·25	—	20·3	33·4	—	23·3
4·50	12·0	25·4	37·9	10·2	16·8
4·75	—	30·0	41·4	—	—
5·00	11·8	37·4	46·7	12·0	8·4
5·25	—	38·7	46·0	—	—
5·50	9·7	34·8	44·0	11·4	5·4
6·00	7·9	23·3	30·1	8·5	3·5
6·50	—	10·8	23·5	7·1	2·8
7·00	4·7	7·0	20·6	6·2	2·1

hydroxide solution ("mercerised") differed from modified celluloses prepared from unmercerised cotton in that their solubility curves in potassium hydroxide solutions had only one maximum. The swelling curves of regenerated cellulose sheet in potassium hydroxide solutions were also found to be of the same shape as the solubility curves. Measurements with these materials have also been made in potassium zincate solutions ($ZnO/KOH=0{\cdot}14$). The swelling of regenerated cellulose sheet (fluidity 38·5) was measured at 15° C. by the method previously described,[3] except that only the swollen weight was determined, and the solubility of this material was measured at 15° C. and 0° C. (the regenerated cellulose being added to the solution at the temperature of extraction). Table VIII gives a comparison of the swelling and solubility results obtained with potassium hydroxide and zincate solutions respectively, the data for potassium hydroxide solutions being taken from Part II[8] ; the solubility curves obtained with the zincate solutions are included in Fig. 8. The Table shows that the swelling at 15° C. is not very different in the two media at

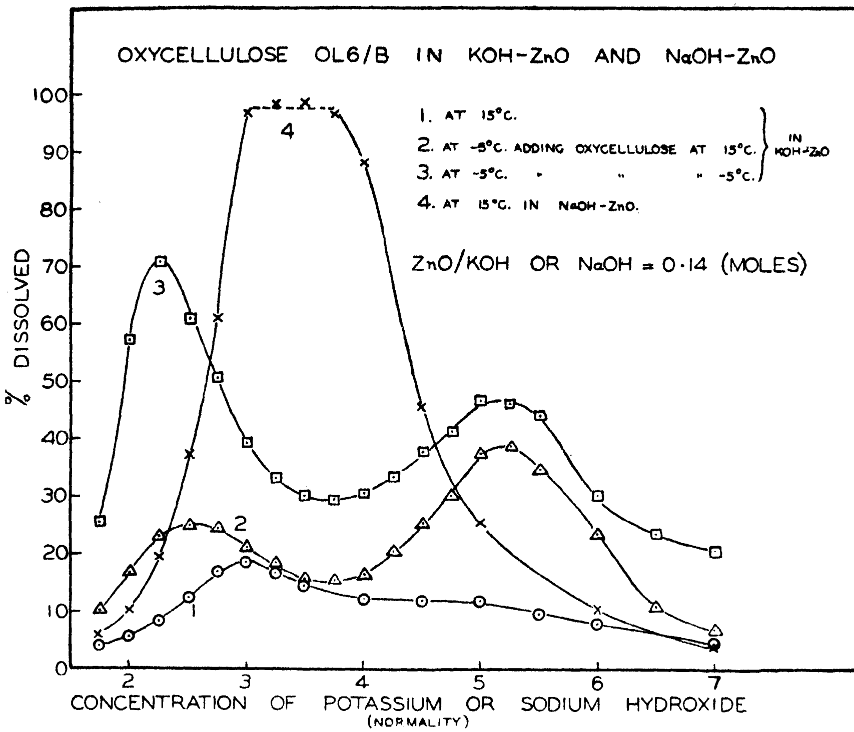

OXYCELLULOSE OL6/B IN KOH-ZnO AND NaOH-ZnO
1. AT 15°C.
2. AT -5°C. ADDING OXYCELLULOSE AT 15°C.
3. AT -5°C. " " " -5°C.
IN KOH-ZnO
4. AT 15°C. IN NaOH-ZnO.
ZnO/KOH OR NaOH = 0·14 (MOLES)
% DISSOLVED
CONCENTRATION OF POTASSIUM OR SODIUM HYDROXIDE
(NORMALITY)

Fig. 7.

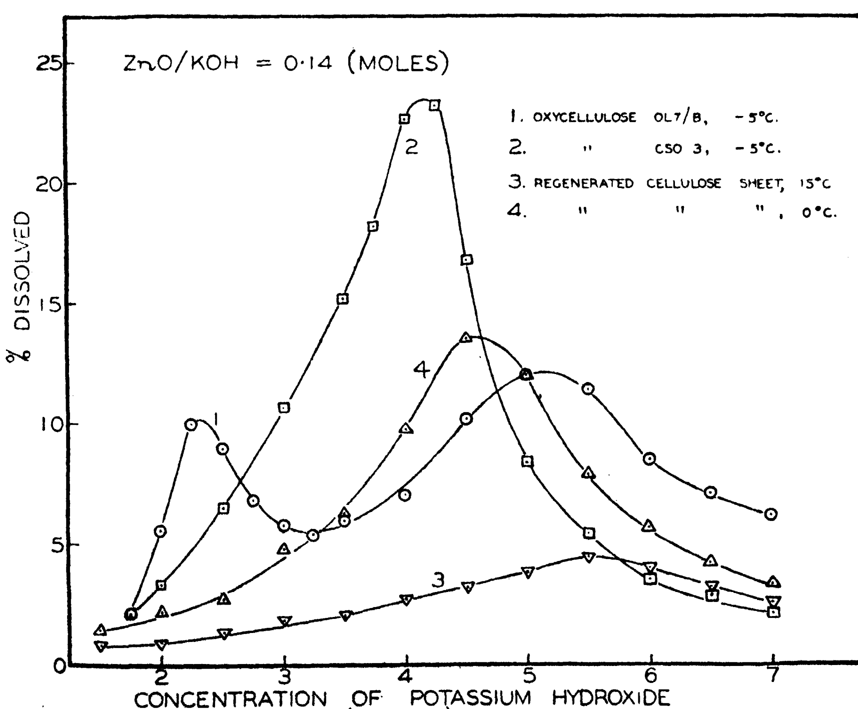

ZnO/KOH = 0·14 (MOLES)
1. OXYCELLULOSE OL7/B, -5°C.
2. " CSO 3, -5°C.
3. REGENERATED CELLULOSE SHEET, 15°C
4. " " " , 0°C.
% DISSOLVED
CONCENTRATION OF POTASSIUM HYDROXIDE
(NORMALITY)

Fig. 8.

concentrations up to $4{\cdot}5N$, but beyond this point the swelling is greater in the potassium zincate solutions. The solvent actions on the regenerated cellulose sheet at 15° C. are similarly related, but at 0° C., where no swelling measurements were made in zincate solutions owing to the greater solubility, the solvent action of the zincate solutions is decidedly greater than that of the hydroxide solutions throughout the concentration range used.

Table VIII
Swelling and Solubility of Regenerated Cellulose Sheet in Potassium Hydroxide and Potassium Zincate Solutions

Concentration of potassium hydroxide (normality at 18° C.)	Swollen weight per 100 gm. dry cellulose		Percentage Dissolved			
	15° C.		15° C.		0° C.	
	Hydroxide	Zincate	Hydroxide	Zincate	Hydroxide	Zincate
1·50	277	—	—	0·8	0·9	1·4
1·75	277	280	—	—	—	—
2·00	279	284	0·8	0·9	1·5	2·2
2·50	291	296	1·1	1·3	2·1	2·7
3·00	317	319	1·7	1·8	3·3	4·8
3·50	357	356	2·0	2·0	4·5	6·2
4·00	400	401	2·6	2·7	6·0	9·8
4·50	448	453	3·2	3·2	7·2	13·6
5·00	508	528	3·4	3·8	6·1	12·0
5·50	540	588	4·0	4·4	5·2	7·9
5·75	532	585	—	—	—	—
6·00	507	558	3·7	4·0	4·4	5·6
6·50	426	444	2·9	3·2	3·6	4·2
7·00	385	391	2·5	2·6	3·1	3·3

Table VII includes the solubility of the oxycelluloses OL7/B (fluidity 34·1) and CSO 3 (fluidity 42·0) in potassium zincate solutions at —5° C., the oxycellulose being added to the solutions at that temperature. The solubility curves are also included in Fig. 8, which shows that, like regenerated cellulose sheet, the oxycellulose CSO 3 gives a curve with a single maximum, whereas the oxycellulose OL7/B gives the type of two-peaked curve found with the oxycellulose OL6/B. The oxycellulose CSO 3 was swollen with concentrated sodium hydroxide solution during its preparation, while the oxycelluloses OL7/B and OL6/B were made from unmercerised cotton. Hence the form of the solubility curve of modified celluloses in potassium zincate as in potassium hydroxide solutions depends on the previous swelling history of the modified cellulose.

(8) The Solvent Action of Sodium Beryllate Solutions.

The solubilities of the oxycellulose OL7/B at 15° C. and of the scoured linters No. 310 at —5° C. were determined in sodium beryllate solutions with

Table IX
Solubility of Oxycellulose OL7/B in Sodium Beryllate Solutions at 15° C.

BeO/NaOH (moles)	Percentage dissolved											
	Concentration of sodium hydroxide (normality)											
	2·00	2·25	2·50	2·75	3·00	3·25	3·50	3·75	4·00	4·50	5·00	6·00
0	1·4	2·5	4·4	7·8	10·5	8·6	6·3	—	3·4	—	1·7	—
0·100	1·2	2·0	4·3	21·0	53·5	67·0	53·9	38·8	26·6	14·3	9·0	3·2
0·200	1·2	—	3·1	10·7	44·7	73·6	77·0	63·9	50·6	27·3	13·2	3·9
0·274	0·9	—	2·5	6·2	32·6	68·8	85·1	77·4	63·6	34·6	18·3	—

various molar ratios of beryllium oxide to sodium hydroxide. The results are given in Tables IX and X respectively, and those for the oxycellulose OL7/B are shown graphically in Fig. 9.

The results obtained are qualitatively similar to those obtained with sodium zincate, but for a given molar ratio of amphoteric oxide to sodium

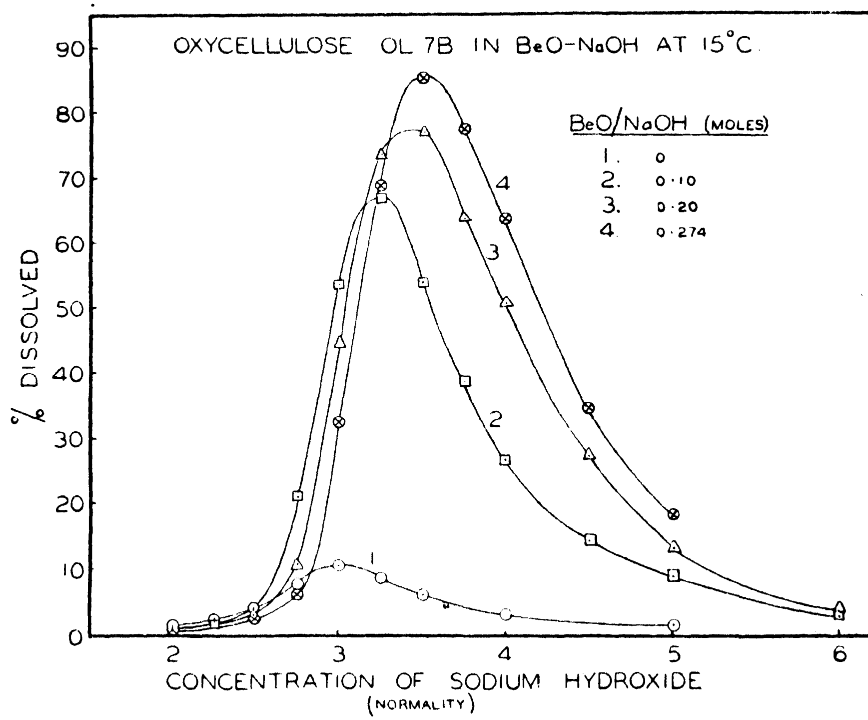


Fig. 9.

hydroxide the beryllate solutions are less effective solvents than the zincate solutions, except at sodium hydroxide concentrations greater than about $4N$. When the molar ratio is low the disparity in the solvent powers at 15° C. is small, but the effect of increasing the molar ratio beyond 0·1 is much less with beryllium than with zinc oxide; at —5° C., the inferiority of the beryllate is pronounced even with a molar ratio of 0·1.

Table X
Solubility of Linters No. 310 in Sodium Beryllate Solutions at —5° C.

BeO/NaOH (moles)	Percentage dissolved								
	Concentration of sodium hydroxide (normality at 18° C.)								
	2·00	2·25	2·50	2·75	3·00	3·25	3·50	4·00	5·00
0	1·3	3·8	5·2	3·5	1·9	—	1·1	0·5	—
0·100	1·1	6·8	18·7	22·9	20·0	6·8	4·3	1·6	0·5
0·200	1·1	2·5	20·8	36·8	33·5	14·6	7·0	3·5	0·5

(9) The Solvent Action of Sodium Aluminate Solutions.

The solubility of the oxycellulose OL7/B was measured at 15° C. and —5° C. in aluminate solutions with molar ratios $Al_2O_3/NaOH$ of 0·025, 0·050

and 0·100, and the results are given in Table XI. Unlike zinc and beryllium oxides, aluminium oxide dissolved in sodium hydroxide solution has the effect of decreasing the solvent action on a modified cotton. As the molar ratio Al_2O_3/NaOH is increased, the maximum solubility of the modified cotton decreases, and the maximum shifts towards higher sodium hydroxide concentrations. This is the kind of effect that would be expected if the solubility of modified cellulose in alkaline solutions depended only on the hydroxyl ion and total electrolyte concentrations. A solution 3·5*N* in total

Table XI

Solubility of Oxycellulose OL7/B in Sodium Aluminate Solutions

Temp. (°C.)	Al_2O_3/NaOH (moles)	Percentage dissolved										
		Concentration of sodium hydroxide (normality at 18° C.)										
		1·75	2·00	2·25	2·50	2·75	3·00	3·25	3·50	3·75	4·0	5·0
15	0	1·0	1·4	2·5	4·4	7·8	**10·5**	8·6	6·3	—	3·4	1·7
	0·025	—	1·3	1·9	2·8	4·7	**7·2**	6·5	5·1	—	3·0	1·7
	0·050	—	1·0	1·5	2·1	2·6	3·8	**4·4**	3·8	—	2·7	1·7
	0·100	—	0·8	1·0	1·4	1·9	2·3	2·6	**2·9**	2·6	2·4	1·5
−5	0	3·3	35·6	72·4	**85·2**	77·4	65·2	—	20·7	—	10·7	3·2
	0·050	1·8	4·8	34·2	68·6	**73·3**	57·5	33·4	21·4	—	10·0	3·2
	0·100	1·5	2·1	4·4	16·0	43·7	**47·0**	29·8	12·6	—	5·5	2·6

(The maximum solubility under each set of conditions is printed in bold type)

sodium hydroxide and containing dissolved amphoteric oxide might have the same hydroxyl ion concentration as a 3·0*N* solution of sodium hydroxide alone, but its total electrolyte content would be greater and hence its solvent power would be less. While this simple explanation would suffice to explain the results obtained with aluminate solutions, the lowering of the solubility of modified cottons produced by zinc and beryllium oxides at low sodium hydroxide concentrations, and the effect of these oxides on the position of the maximum in the solubility curve, it throws no light on the causes of the enhanced solvent action of zincate and beryllate solutions at higher sodium hydroxide concentrations.

REFERENCES

[1] Birtwell, Clibbens and Geake. *Shirley Inst. Mem.*, 1928, **7**, 45 ; or *J. Text. Inst.*, 1928, **19**, T349.
[2] Davidson. *Shirley Inst. Mem.*, 1934, **13**, 1 ; or *J. Text. Inst.*, 1934, **25**, T174.
[3] Davidson. *Shirley Inst. Mem.*, 1935, **14**, 43 ; or *J. Text. Inst.*, 1936, **27**, T112.
[4] Fricke and Humme. *Z. anorg. Chem.*, 1928, **172**, 234.
[5] Goudriaan. *Rec. trav. chim.*, 1920, **39**, 505.
[6] Lewis. *J. Text. Inst.*, 1933, **24**, T122.
[7] Lowe. E.P.20,314 (1889).
[8] Müller. *Z. Elektrochemie*, 1927, **33**, 134.
[9] Parnell. " Life and Labours of John Mercer," p. 201 (London, 1886).

Received 1/2/37

THE JOURNAL OF THE

TEXTILE INSTITUTE

TRANSACTIONS

5—THE GEOMETRY OF CLOTH STRUCTURE

By FREDERICK THOMAS PEIRCE, D.Sc., F.Inst.P., F.T.I.

(The British Cotton Industry Research Association)

INTRODUCTION

Fibres, yarns and fabrics are not regular structures capable of description in mathematical form, even to the degree of approximation attainable by the simplest physical measurements. To reduce observations on actual specimens to quantitative relations of any general validity, statistical methods are necessary, with all their reservations of error, variation and uncertainty. Nevertheless, there is a correspondence between the underlying regularities which emerge from statistical analysis on the one hand, and, on the other, the mathematical deductions obtained by assuming simple geometric forms and physical characters, which idealise the general character of the materials. If used with discretion, tempered by constant reference to practical experience, such mathematics may be used to suggest the form to which observations should be reduced and in which they should have the most general validity.

It is only within the limitations of such a cautious view that the following discussion is put forward. The assumptions are not hypotheses about the character of any actual materials which some future critic may test, nor are the deductions intended to be speculations or predictions on the results of such tests. The mere indiscriminate substitution of test results in the formulae may not represent the best use that can be made of the theory. On the other hand, the theory is not merely an exercise in mathematics but has been found useful in the ordering and interpretation of observations. It allows estimates to be made of purely geometrical effects so that a better measure may be obtained of other effects, such as physical changes due to tension or swelling, statistical effects of internal variation, and so forth.

As the treatment develops, further and more complex assumptions will be made to attain a further degree of approximation to the statistical facts of

experiment. Physical and statistical theories may be combined with the geometrical theory to give a fuller account of various phenomena. The present paper is not intended to describe such applications and, if experimental data are introduced at all, it is merely to explain the theory, which must be judged by its accordance with the assumptions and not with particular pieces of cloth. That criterion may be used when an experimental investigation is interpreted on the basis of the theory, or of any extension thereof which may be called for by the nature of the case.

In Part I, on " Geometrical Similarity," certain quantities are introduced which facilitate general comparison between fabrics on the basis of their geometrical form and allow experimental data to be expressed in a manner best adapted to the application of geometrical analysis.

In Part II, on " The Geometry of the Plain Weave," the relations between the spacings and crimps of warp and weft are deduced from the simplest assumptions, and formulae are obtained suitable for application to practical problems. The manner of such application is then discussed for a number of problems of special interest.

In Part III, deviations from the simple geometry are discussed—first, the effect of the " Compression of Threads". It appears that the deductions from the ideal geometry may be modified very simply to allow for most of the effect of compression. A short note is added on " Twills and Matt Weaves," but deductions from the simplest assumptions have only a limited application here, to be made with much discrimination, and fuller discussion is best deferred to experimental studies on these weaves, where assumption may be tested against actuality. Another section is devoted to the " Crimped Form of Elastic Threads". The assumptions made are intended even less than those of the simple geometry to describe actual materials and the theory is given merely to suggest the form in which the effects of rigid resistance in the threads may be expressed.

In Part IV, some applications of the theoretical relations to experimental data on cloths are described in a number of " Practical Illustrations and Examples". A summary of the results of the analyses is given at the end. Further work is now being done at the Shirley Institute to extend the analysis to the problems of the distortion of finite areas of cloth by stress, using the methods of differential geometry in which the warp and weft threads are taken as co-ordinates. (See the next paper, by Womersley, p.T97.)

Some of the simpler geometrical relations given in this paper are well known in the teaching of weaving and are embodied in empirical rules for the sett of fabrics. It is not part of the present purpose to review the extensive literature on this subject, though this furnishes a useful preparation for the more thorough application of geometry to cloth. The familiar relations are included here in a concise general form, not as rules for the immediate guidance of cloth designers, but as part of a coherent analytical system of geometry, intended as a basis for the study of the physical behaviour of fabrics.

Sections printed in small type are included for those who wish to consider critically the mathematical theory and may well be omitted by the technical reader.

PART I
GEOMETRICAL SIMILARITY

In engineering practice, when the relations between the parts of a structure are to be studied, it is usual to draw diagrams to scale. These are valid for any size of structure—one and the same might do for a " Meccano " toy or a great bridge. To calculate the behaviour of the structure—its strains and strength, weight, etc.—tests are not made on identical objects but on specimens of convenient size and shape from which specific constants are determined. For most properties of common importance, tables of constants are published by which a vast accumulation of experience is made available for general use.

It is true that the actual behaviour of structures is not precisely calculable by geometry and specific constants on the assumption that scale, *per se*, has no effect—the molecules and the world do not alter their dimensions as the scale is altered ; but the effect of absolute scale is often a small or " second order " effect which may be neglected or corrected by rule of thumb or physical law, the discovery of which is greatly facilitated by the primary calculations on the basis of geometry and constants.

In textile technology, it is still usual to express cloth structure and properties by particular measurements which confuse and conceal the relations between the parts—staple length and hair-weight per centimetre, hanks of various length per pound, twists per inch, threads per inch (if not Stockport reed), strength in pounds per lea or per inch width, weight in ounces per linear yard, thickness in mils or millimetres, etc. It would need a prodigious memory to co-ordinate experience in a general scheme when expressed in this way. So, in fact, experts gain knowledge and familiarity with small ranges of types of cotton, yarn and cloth ; and these fragments of knowledge remain isolated and particular.

In order to bring into clearer relief the regularities in textile materials, such as the relation between cloth structure and strength, it is necessary to adopt a scale on which to compare fabrics differing in mere size, that is, by the gross features of counts and threads per inch. The device is not unknown and merely calls for more systematic development and use. The most familiar example is the use of the twist factor of yarn ; it is far easier to gain and remember general knowledge of the effect of twist on hardness, strength and extensibility of yarn in terms of this factor than of turns per inch. Similarly, the count-strength product gives a better general criterion of the success of spinning or of the spinning value of a cotton than does the breaking load at a particular count. These " constants " are not precisely independent of the count but sufficiently so to facilitate greatly the comparison of yarns differing in count.

In metal structures, the scale is determined by direct gauge measurements of length. It is not necessary nor convenient to adopt the same method and system of constants for textiles, as the linear dimensions of yarn and fabric are rather indefinite and very unstable. Weight is the basis for specifying size in textiles and it is advisable to retain it as the basis of geometrical ratios and physical constants. Thus, the twist might be expressed geometrically by the number of turns in a length proportional to the diameter. If the density or " specific volume " is constant, this scale length is proportional to the inverse square root of the count ; and the twist expressed in this unit of length is the twist factor. The relation between the

engineer's scale of length and the textile scale of the inverse square root of the count depends on the specific volume.

Many physical constants might be adapted for application to textiles but those of only special interest may best be considered in discussions of specialised scope. Here the intention is to introduce certain quantities, ratios and constants, which are of general value in cloth analysis and problems of structure and strength.

Apart from questions of regularity and more subtle qualities, the formal structure of a cloth is defined by: threads per inch, crimps, counts of warp and weft—the six quantities obtained by the usual cloth analysis. Geometrically, the structure of the weave may be described by the paths of the central axes of the yarns, defined by the spacing of the threads, the crimps and the closest approach between the two axes. The last quantity is the natural scale of the structure; but, as one does not take measurements to the centre of yarns, it is better to double it and take as the unit of scale the sum of the diameters of the yarns. In practice, the count is a better measure of size than diameter, hence it is necessary to make the link between geometry and cloth analysis by relating count with diameter.

Specific Volume

v The specific volume, v, is the ratio of the volume occupied by a material
d to that of the same weight of water. If d be the diameter in inches of a yarn
N of (cotton) count N;

$$v = 858Nd^2 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (1)$$

y or more generally $v = 1{\cdot}02147.yNd^2$, where N is the number of units (hanks) of length y yards in a pound of yarn. For direct comparison with threads per inch, it is common to express the diameter by its reciprocal, $1/d$, the number of diameters per inch. In the cotton system,

$$1/d = 29{\cdot}3\sqrt{N/v} \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

The volume occupied by yarn or cloth is a somewhat indefinite quantity and in practice is the apparent volume derived from some test, in which arbitrary features enter, so that the apparent specific volume varies with the method of measurement as well as with the twist, tension, treatment, etc., of the yarn. For cloth geometry, the apparent specific volume may be taken as the value obtained by substituting observed values, from fabric conforming well to the assumptions, in the analytical relations given in the next part of this paper. It appears that under the compression of the woven structure, a constant value, $v = 1{\cdot}1$, may be assumed for cotton yarn. Observations on hard twisted yarns* and on sized yarns yield similar values.

Assuming this value and rounding off the factor to the nearest unit;

$$1/d = 28\sqrt{N}$$

The relation, that $1/d$ is proportional to $\sqrt{N}$, is familiar in textile technology, though the factor given is usually less. The "*Textile Manufacturer*" Year Book (1932-3, p. 136) gives the formula incorrectly but supplies tables based on the correct form, with a factor 26·1, i.e. an apparent specific volume of 1·26. Such higher values are obtained in measurements by the rod-winding method, in which there is some flattening

* The best estimate was obtained from measurements on a rope of very soft yarns. On twisting this, the resistance was at first small, then it suddenly increased and the rope became quite hard. It then had a very definite and regular diameter, from measurements on which the specific volume was 1·1.

which broadens the yarn, and by the photo-electric method in which stray hairs exaggerate the diameter and also arise from the real looseness of structure of many yarns under no compression. It appeared best, in the development of cloth geometry, to assume a constant uniform value of 1·1 for the specific volume of the threads and to allow for variations of apparent diameter by assuming distortion or flattening.

The apparent specific volume of cloth, calculated from a measurement of thickness by any uniform method, is also of value in the study of many physical properties. If G be the thickness ("gauge") in mils (1/1000″) of a cloth weighing W oz. per sq. yd. G W

$$v = 0{\cdot}75\, G/W \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

The specific volume of the cotton cellulose itself is 0·64. If a cloth showed a value of 2·0, and that would be a dense cloth, this would indicate that there was rather more than twice as much air space as solid material in the volume occupied by the cloth. Such space is a most important feature, having great influence on the warmth of clothing, on permeability to air and moisture, on the absorption of liquids, and on strength and extensibility.

The scale unit of cloth structure is the length equal to the sum of the diameters of the two yarns, warp and weft. Taking count as the practical measure of size, 1·1 as the effective specific volume, and rounding off the factor, this scale unit

$$D = 36\ (1/\sqrt{N_1} + 1/\sqrt{N_2})\ \text{mils} \quad \dots \quad \dots \quad \dots \quad (4)$$ D

for threads of circular section, where the suffices 1 and 2 refer to warp and weft respectively.

The form of the pattern made by the yarn axes is defined by the threads per inch and crimps, its scale by this unit D; but fabrics of very different type, weight and cover, might have the same pattern and scale, as the relative size of warp and weft yarns is still undefined. This feature may be supplied by the ratio, $\beta = \sqrt{N_1/N_2}$. Good use can also be made of the direct comparison of yarn diameter and spacing, of warp and weft separately.

Cover Factor.

The ratio of threads per inch to the square root of the count may be called the "cover factor," K. It is of similar form to the twist factor and is as useful in dealing with reed and pick changes as this is in spinning. If p be the spacing in mils, K p

$$K = 1000/p\sqrt{N} = 28\ d/p \quad \dots \quad \dots \quad \dots \quad (5)$$

where d is also in mils and a specific volume of about 1·1 is assumed. The cover factor thus indicates the degree of closing or cover, the proportion of the area which is covered by the projection of the threads.

It is well known that ooziness of yarn, flattening in finishing and regularity improve the cover of cloth, so that the indication given by the cover factor is not a sufficient measure of this quality but it gives a very suitable basis of comparison for any experimental investigation, not only of cover but also of hardness, crimp, permeability and transparency, limits of picking, etc., in which fabrics of similar cover factors show similarity.

It would appear from Equation (5) that when the cover factor is 28, the threads must touch where they cross from one face of the cloth to the other. Higher cover factors can only be attained by lateral compression of the threads or some distortion of the structure. The cover factor is further limited by the necessity to make room for the cross-threads to pass, so that

very high values are only possible in one direction, in which the threads have a high crimp. The value 28 is actually about the limit of values found in tent canvas and poplin, which have this structure, though values down to 20 represent reasonably close fabrics of this type. The weft will then usually not show a factor of more than 10 or so. The closest square fabrics only show factors up to some 16×16 but 12×12 represents quite a solid commercial plain cloth. Below 10×10, the type of cloth is encountered where threadiness and transparency are desired, such as voile, mull, organdie, and cheesecloth, in which 8×8 is normal. The values found in commercial fabrics are discussed more fully on p. T77, *et seq.*

For other fibres and systems of yarn numbering, cover factors may be calculated in the same way for internal comparisons. For general comparisons, the factors on all systems may be reduced to the absolute ratio d/p. In the cotton system,

$$d/p = 0{\cdot}03414\sqrt{v}.K = K/27{\cdot}93\sqrt{1{\cdot}1/v}. \qquad \ldots \quad (6)$$

In any other system, the factor 27·93 will be replaced by another figure, also representing the value of the cover factor when the spacing is barely equal to the diameter of the threads, assuming a specific volume of 1·1 or other value more suited to the material. In the worsted system ($v = 1{\cdot}1$), the factor is 22·80 ; in the woollen (Yorkshire skein) 15·42 ; in the linen (leas per pound) 16·69 ; in the "Typp" (thousand-yards per lb.) system 30·47. While it is possible that the standard value of specific volume, 1·1, may need adjustment for some fibres, it appears on present evidence to be a reasonably good approximation for most textile materials.

In the direct systems of numbering (weight per unit length), the cover factor would be calculated by *multiplying* the threads per inch by the square root of the yarn number, and Equation (6) still applies, with appropriate factors. For grams per metre, the factor is 21·46 ; for denier 2036 ; for pounds per spindle (flax, jute and hemp) 115·6.

Although occasional use is made of the idea of adjusting picks per inch to proportionality with the square root of the counts in order to maintain constant cover, the chief value of the device only comes from systematic use so that the characteristics associated with different values and pairs of values of cover factors become familiar by experience. Take for an example in the woollen system, the range of Saxony Suitings given in the "*Textile Manufacturer*" Year Book, 1932, p. 274. These may be described as 2/2 twills with cover factors about 9 each way and with weft counts equal to or slightly coarser than the warp counts, which vary from 33 to 13 skeins. Such a description facilitates the design of a suiting of any desired weight and co-ordinates all experience of the various characteristics of the whole range of materials. It also provides a convenient method of defining the range of structures which may be included under one name—poplin, canvas, cambric, limbric, etc.

Crimp.

Crimp (c per cent.), geometrically considered, is the percentage excess of length of the yarn axis over the cloth length. It is not practicable to measure the length of the yarn axis directly and it is estimated by removing and straightening the thread under a standard tension. Tension extends the thread before it removes the corrugations completely and a value must be chosen at which these two errors cancel each other. It is not practicable

to make a special research to determine this value for each cloth but a good general formula is to use a tension of $16/N$ oz., the weight of one hank. (One of the purposes of this analysis is to develop methods of determining cloth structure by direct microscopic measurement, without pulling the threads apart.)

Crimp is a geometrical ratio, independent of scale or weight among geometrically similar fabrics. There is a close relation between crimp and cover factor, so that a rough idea of the crimps to be expected in a cloth is obtained from the cover factors, after some experience of the use of the latter quantity. Thus, to anticipate relations obtained from the geometrical theory, in plain cloths of roughly square structure, the sum of the square roots of the two crimps is equal to about one quarter of the sum of the cover factors, when, as in a voile, the threads have been flattened little ; smaller values of crimp, say in calendered cloth, indicate the degree of flattening.

In crammed fabrics with soft yarns, particularly after mechanical finishing treatments, the actual structure becomes distorted out of any similarity to the simple geometrical forms assumed in analysis, e.g. the yarn is indented rather than bent. Crimp and similar features then become indefinite in a geometrical sense but the methods of test developed on more ideal forms may still be applied and their results remain useful, though more caution is necessary in their interpretation.

Weight.

Practical problems are commonly of the form in which the scales of two or more similar fabrics are determined by their weight. It is therefore useful to express the weight as the product of a form factor and the scale unit, the inverse square root of the warp count. A simple calculation gives this formula for the weight in ounces per square yard :

$$W = 1/\sqrt{N_1} \times 0{\cdot}6857\,[K_1(1 + c_1) + K_2(1 + c_2)\beta] = w/\sqrt{N_1} \quad (7). \qquad w$$

where the suffices 1 and 2 refer to warp and weft respectively, $\beta = \sqrt{N_1/N_2}$, and the crimps (c_1 and c_2) are given as proportions, not percentages. The factor w may then be called the weight factor.

The separation of unit of scale from the factor of form greatly aids general comparisons between fabrics in studies of many properties, though the explanation of the use of the device for particular physical studies must be left to special discussions. It might appear, however, that there are still so many features affecting the form factors that comparisons would still be very complex, in that these features may all vary independently. Though this is true if comparisons are to cover all possible forms of fabric, the complexity is greatly minimised in practice by the actual relations between the various features which are found in large and important groups of fabrics. In a wide variety of plain-weave cloths, warp and weft are so similar in count that the variations of β do not prevent general comparison. In the more open types, the two cover factors are approximately equal, so that their mean or sum serves as a basis of comparison. In closer types, when the cover factor in cotton exceeds about 16 in either direction, another form predominates in which cover depends almost entirely on one of the factors, usually that of the warp, which is of the order of 20 or more, and the other cover factor has minor influence and is about half as great. The great bulk of commercial plain cloths thus reduce to a single series, including fine muslin, voile and cheesecloth, shirtings, sheetings and poplins, tyre

fabrics and tent canvas, within which general comparisons are comparatively simple.

In some connections it is useful to combine the two cover factors in an expression suggested by simple geometry. Assuming circular threads of uniform density, such that a complete layer would have a cover factor K_0 (28 in cotton of specific volume 1·1), the proportion of the area covered by the projection of both threads may be called the cloth cover,
C $C = (K_1 + K_2)/K_0 - K_1K_2/K_0^2$.

In saying that a wide variety of fabrics may be reduced to a single series for comparison, no suggestion is implied that a single feature determines their character and properties. The basis of general comparison is sought rather to eliminate the gross features of scale and cover in order to see more clearly the very important effects of crimp, twist, staple and other internal features. These also may often be expressed as factors, in terms of the inverse square root of the counts, with advantage to generality.

Twist Factor.

k, τ The twist factor, $k = \tau/\sqrt{N}$, where τ is the turns per inch, is the most familiar of such factors. For yarns of similar specific volume, this factor defines the angle of twist—the tangent of the angle between surface fibres and yarn generator being given in ideal geometry by

$$\begin{aligned} \tan x &= \pi d\tau/1000 \\ &= 0{\cdot}107\sqrt{v}.k \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8) \\ &= k/9, \text{ when } v = 1{\cdot}1 \end{aligned}$$

It is well known that, while twist factor provides the best basis for general statements on hardness, strength, extensibility, etc., of yarns, its effect is not absolutely independent of the count of yarn or of the staple of cotton. For instance, the twist factor for maximum strength drifts downwards for coarser counts of a given cotton, but upwards for coarser, shorter cottons in a given count. This is mainly because the fibre dimensions do not vary with the counts to maintain geometrical similarity in the fine structure of the yarns.

Fibre characters may also be expressed in a manner which eliminates scale from general comparisons, analogous to that adopted for yarns. The diameter or transverse dimension ($1/\sqrt{N}$ in the case of yarn) will then be
H expressed by $\sqrt{H}$, where H is the hair-weight per centimetre of the cotton, and this becomes the unit of length. The effective or staple length (L) is then expressed as $L/\sqrt{H}$, a measure of the geometrical feature, the ratio of length to diameter; and the count of the yarn by N/H, a ratio inversely proportional to the number of hairs per cross-section. This is, however, a wide subject, further discussion of which must be left to another occasion.

The use of geometrical factors may be illustrated by a simple example of cloth design. A canvas had been found very satisfactory for a special purpose, in which permeability was an essential feature; but a lighter fabric was desired. In place of a cloth weighing 11½ oz. per sq. yd., one weighing 8½ oz. was wanted. The fabric had 51 × 42 threads per inch of 2/13's (i.e., the yarn count was 13/2), with 13½ doubling turns per inch. In a cloth geometrically similar, the proportion of open space will be the same. Such a cloth, of weight 8½ oz., is found by Equation (7), as all the geometrical factors are unchanged and the new scale is given by the warp count,

$N_1 = (13/2) \times (11{\cdot}5/8{\cdot}5)^2 = 23{\cdot}8/2$. The cover factors, remaining $20 \times 16\frac{1}{2}$, give 69×57 threads per inch and the twist factor of 5·3 gives 18 turns per inch. A cloth with these particulars may reasonably be taken for a first attempt at substituting the original by a lighter cloth of similar performance in regard to permeation of gas. Minor adjustment of permeability could be made in finishing by control of crimp. In the original, the crimps were 27 per cent. in warp and 5 per cent. in weft, and these could be matched as they are geometrical ratios.

A more thorough theoretical study of permeability demands a study of the flow of gases through fabrics and its dependence on scale. On the simple law of viscous flow in tubes, the permeability of similar fabrics should vary directly with the linear dimensions, but if the flow is considered as effusion through small holes in a thin lamina, the permeability would vary inversely with dimensions. Diffusion and turbulent flow are governed by more complex relations. The actual behaviour in use cannot easily be predicted with high accuracy and would depend on the exact conditions of use. The air permeability, as determined in the laboratory test,* may be taken as a sufficient guide, at least till actual experience gives its final word. The value obtained on the original cloth mentioned above was 111 and the figure of 117 was obtained on a cloth approximating to the calculated construction, viz. a weight of $8\frac{1}{2}$ oz., with 65×57 threads per inch of 2/23's. The effect of mere scale on air permeability is therefore quite small, but it would not be small on resistance to water penetration, the physics of which is quite different.

If any form of physical behaviour—permeability, water-proof quality, filtering, strength, etc.—is not independent of scale, it is no less important and useful to separate the effects of geometrical form and of absolute dimensions. General relations may often be obtained more easily and more simply expressed by the use of physical " constants " independent of scale. The systematic adaptation of such quantities to textiles is too wide a subject for present discussion, and one familiar example only will be given for illustration.

Breaking Length.

Breaking length is the length of material, similar to that of the specimen tested, of weight equal to the breaking load. This serves the purpose, in textiles, of the specific tenacity by which the strength of engineering materials is commonly expressed, viz. pounds of breaking load per square inch of cross section. More generally, instead of stress (force per unit area), it is more convenient to express tension in textile materials as a ratio to the weight per unit length. If S be the stress in kilograms per sq. cm. and B the length in hanks of 840 yards of material of weight equal to the tension, $B = 0{\cdot}013.v.S$, or $S/70$, assuming $v = 1{\cdot}1$. S, B

The breaking length of a thread of strength F_y oz. is $F_yN/16$ hanks. This applies to any yarn-numbering system in which the count is the number of hanks per pound. The count-strength product of leas of cotton yarn is in the same unit, the hank of 840 yards, though the strength is that of F_y

* F. H. Clayton. *Shirley Inst. Mem.*, 1934, **13**, 101-117 ; or *J. Text. Inst.*, 1935, **26**, T171-186.

160 parallel threads. The standard count for carded yarn by which the spinning value of a cotton is assessed at the Shirley Institute is that at which the count strength product is 2000.

F_c Cloth with a breaking load of F_c lb. per inch width has a breaking length of 576 F_c/W yards. A square cotton cloth of high quality, designed for strength, should show a value exceeding 10,000 yards; and this is a criterion familiar to textile inspectors in Government Services. In studying its relation to cloth structure, the strength may better be expressed by the
t breaking length of the threads under tension, F_cN/t hanks, where t is the number of threads per inch. This quantity is greatly influenced by cloth structure and can by no means be taken as a measure of the intrinsic strength of the fibre or of the quality of the yarn alone. The breaking length of well-made bundles of cotton fibres is about 40 hanks, a value useful as an upper limit in studying the variations of cloth thread breaking lengths.

The other important feature of tensile tests, the breaking extension, is normally expressed as a ratio, and as such is immediately suited to general analyses. The breaking extension of cloth is roughly equal to the sum of that of the yarn and the crimp. Crimp has also a marked influence on the strength and should always be measured and published in any study of cloth strength. Many complex features influence such studies, so that no one investigation can cover them all. It would greatly advance the state of knowledge on the subject if each investigator gave sufficient data at least to determine the features discussed in the above pages.

PART II

THE GEOMETRY OF THE PLAIN WEAVE

Everyone familiar with the subject will be aware of many features of cloth behaviour which are essentially geometrical, though the knowledge may be vague and qualitative. For example, there is an upper limit, depending on the counts, of picks per inch in a cloth of low reed; the limit of picks per inch is much lower when the ends are nearly crammed; the limit of threads per inch in a square cloth is intermediate; the weft dimension decreases and weft crimp increases when the cloth is stretched in the warp direction; cloth shrinks when the fibres swell on wetting, etc. Cloth behaviour is also affected by stretching and compression of the yarns, but these effects can be isolated only after calculating the purely geometrical relations and they are much the same in different structures.

Crimp-Spacing Relation.

The first considerations calling for mathematical treatment are the mere spatial necessities of fitting yarns together into a fabric—the relations between the size of the yarns, their spacing and bending. For this purpose, the yarns will at first be assumed flexible, circular cylinders interwoven in a regularly recurring pattern. The simplest pattern is that of the plain weave, undistorted and lying flat, of which a section is shown diagrammatically in Fig. 1. This section is in the plane of the axis of a warp yarn, which is normal to the "plane of the cloth," the central plane equidistant from the two tangential planes that enclose the paths of the warp (or the weft) yarns.

The notation to be used throughout will be as follows:

Diameter of thread of warp ... ... d_1, of weft d_2 mils.
Spacing of threads of warp ... ... p_1, „ „ p_2 mils.
Maximum angle of the thread axis to plane of cloth θ_1, „ „ θ_2 radians θ
Length of thread axis between planes containing the axes of consecutive cross threads ... ... l_1, „ „ l_2 mils. l
Maximum displacement of the thread axis, normal to the plane of the cloth ... ... h_1, „ „ h_2 mils. h
Crimp (fractional, not percentage) ... ... c_1, „ „ c_2

If in any relation no suffices are used, it is to be understood that either 1 or 2 may be inserted throughout; any relation remains equally valid on consistent interchange of these two suffices. It is clear that geometrical relations will be independent of the scale. To maintain general and symmetrical forms, the basic length determining the scale will be the sum of the diameters, $D = d_1 + d_2$.

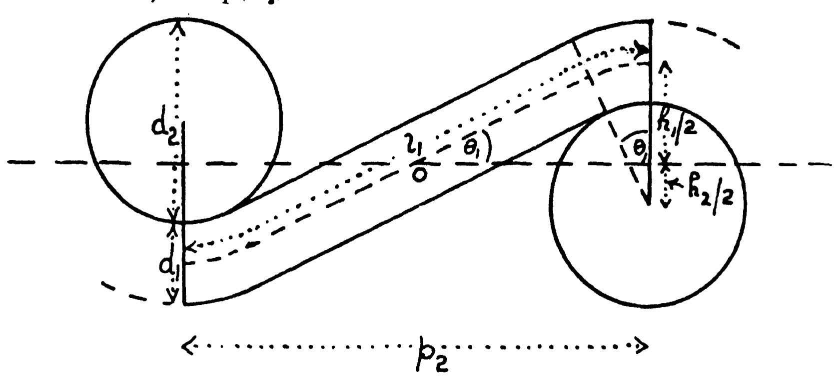


Fig. 1.

The relations sought are those between the observable quantities of cloth structure, threads per inch (or spacing), counts (or diameters) and crimps, whereas the immediately evident geometrical relations are in terms of l and θ, which are to be eliminated.

By definition, $c_1 = \frac{l_1}{p_2} - 1$ ... ... (9)

By projecting, parallel and normal to the cloth plane, the straight portion of the axis and the arcs at its ends, the pick spacing,

$$p_2 = (l_1 - D\theta_1) \cos \theta_1 + D \sin \theta_1 \quad \dots \quad \dots (10)$$

and the total vertical displacement

$$h_1 = (l_1 - D\theta_1) \sin \theta_1 + D\,(1 - \cos \theta_1) \dots \quad \dots (11)$$

The mutual relation between the paths of the two sets of threads is given by the fact that the sum of the two displacements from the central plane of the cloth is equal to the sum of the radii

$$h_1 + h_2 = D \dots \quad \dots \quad \dots \quad \dots \quad \dots (12)$$

With the equations for the weft corresponding to Equations (9)—(11), there are now seven equations connecting the eleven quantities $D, p_1, p_2, c_1, c_2, l_1, l_2, \theta_1, \theta_2, h_1, h_2$. If, therefore, any four of these are known, the rest are determined. For instance, if both spacings and crimps are known, the sum of the diameters may be calculated. Then, if the warp is extended by a known amount without stretching, compression or slippage of threads, D, p_2, l_1 and l_2 are known so that the weft dimension and the crimps may be calculated.

The equations as they stand are distinctly awkward to handle, except when the values of θ_1 and θ_2 are known. Usually these are neither known nor wanted and, for the practical utility of the analysis, it is almost essential to eliminate them. As it is not possible to do this algebraically for all the relations between the other quantities, the following sections are devoted to special cases, approximations and tabulations in which the relations are expressed in applicable form. (For later reference, it may be noted here that the thickness of the cloth $G = h + d$, using the suffix which gives the greater value.)

The best that can be done to eliminate l and θ analytically is as follows: From (10) and (11) we have

$$(l_1 - D\theta_1) = \frac{p_2 - D\sin\theta_1}{\cos\theta_1} = \frac{h_1 - D(1 - \cos\theta_1)}{\sin\theta_1}$$

$$\text{or } D(\sec\theta_1 - 1) - p_2\tan\theta_1 + h_1 = 0 \quad \ldots \quad (13)$$

This may be expressed algebraically by the substitution, $t_1 = \tan\theta_1/2$ giving

$$t_1^2(D - h_1/2) - p_2 t_1 + h_1/2 = 0 \quad \ldots \quad (14)$$

For real fabrics there is only one root to this equation,

$$t_1 = \frac{p_2 - \sqrt{p_2^2 - 2h_1(D - h_1/2)}}{2D - h_1} = \frac{p_2 - \sqrt{p_2^2 + h_2^2 - D^2}}{D + h_2} \quad \ldots \quad (15)$$

This may on occasion serve for the explicit calculation of t and hence of θ, l and c, but it does not allow this in general for any set of knowns and unknowns. The other equation obtained by eliminating l, from (9) and (10), is more awkward,

$$l_1 = p_2(1 + c_1) = D\theta_1 + \frac{p_2 - D\sin\theta_1}{\cos\theta_1}$$

This cannot be simplified by substituting t, which gives only

$$\frac{c_1}{2} + t_1 . \frac{D}{p_2} - t_1^2\left(1 + \frac{c_1}{2}\right) = \frac{D}{p_2}(1 - t_1^2) . \tan^{-1} t_1 \ldots \quad \ldots \quad (16)$$

This cannot be solved algebraically for t_1 but the value given by (15) may be substituted in (16) to give an equation from which l and θ are formally eliminated. It is, however, so clumsy that there is no point in writing it out. Nor is it possible to solve this equation for h explicitly and so obtain the terms which, substituted in (12) would give the equation ultimately desired between p_1, p_2, c_1, c_2 and D.

For practical purposes, the essential equation connecting p_1, p_2, c_1, c_2 and D is best obtained by tabulation of the values of p, h, and c calculated for intervals of l and θ. If D be taken as the unit of length, these values are easily calculated to any desired accuracy with the aid of familiar trigonometrical tables. Graphs may then be plotted for constant values of l, one set connecting c and p, the other c and h. From these curves, values of p and h are read off at equal values of l and c, and these are plotted against each other on curves for constant values of c. It is preferable to use the curves of equal values of l rather than those of θ, as they show directly the structural changes which occur in crimp interchange or alteration of dimensions, when the threads remain constant in length.

This graphical method, carried out on a large scale with accurately ruled paper, gives higher accuracy than can ever be matched by observation but, as the analysis of geometry was developed, it was considered desirable to replace it by pure computation. This has been carried out by Womersley, with the aid of calculating machines and sound methods of interpolation. Many of the relations obtained, as graphs or tables, are of interest and may be applied in various problems but it is impracticable to reproduce all here. The relations between the observable features are perhaps shown best by the curves (almost straight lines) of constant crimp c, against spacing, p/D and amplitude, h/D, which are reproduced in Fig. 2. For rigorous computations, the most convenient form was considered to be a table of h/D in terms of l/D and $(l - p)/D$, given in Table I. Other relations

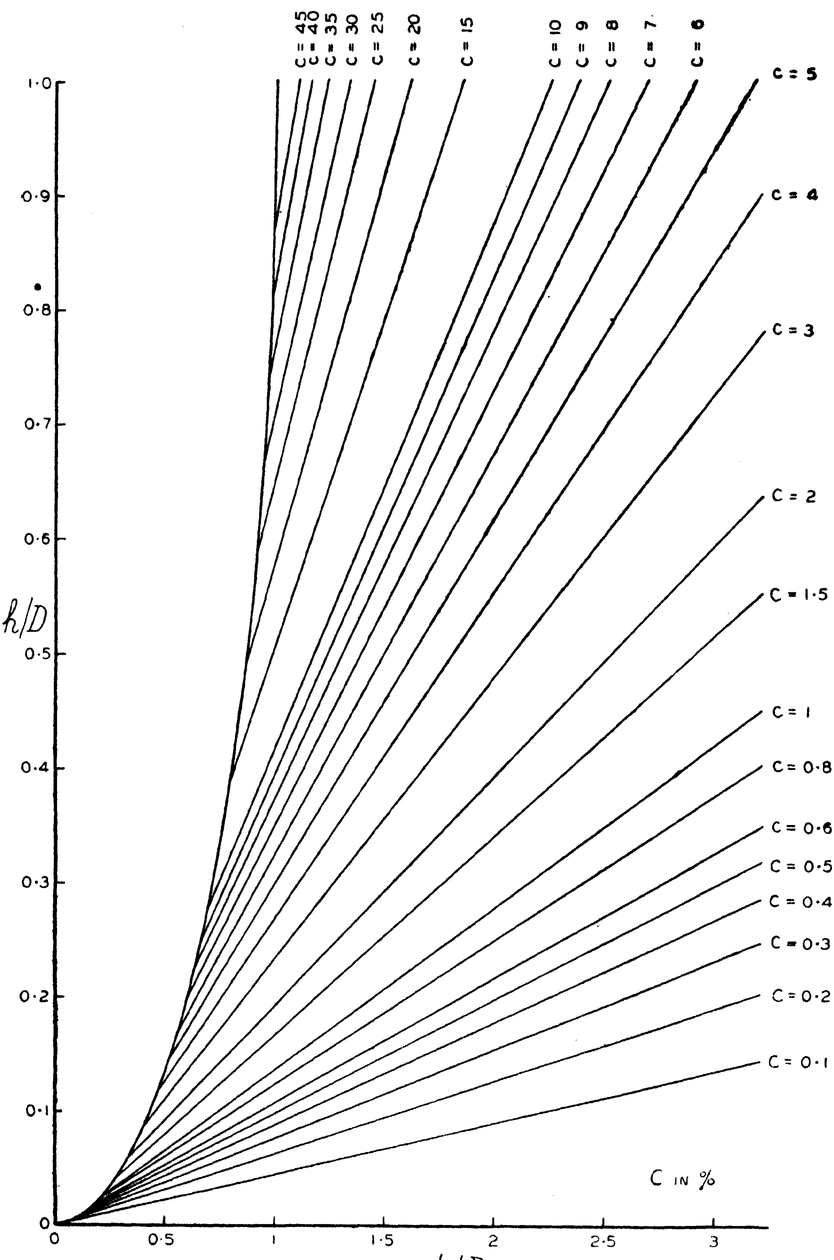


Fig. 2.

and a fuller description of the methods of computation will be given in the further work referred to towards the end of the Introduction to this paper.

An accuracy comfortably greater than that attainable in any measurements on fabrics may be attained by a mechanical device or nomogram, which is really a large scale model of half of Fig. 1. A drawing of this is reproduced in Fig. 3. It consists of a quadrant of wood or metal, accurately

turned to a radius of 10 cm., mounted on a rectangular baseboard, which is covered with squared paper. The values of p/D are marked, 1 unit = 10 cm., from left to right along a horizontal line of the paper, tangential to the quadrant, the zero being at the point of contact. A thin steel tape is fastened by one end to the edge of the quadrant to the left of the zero and is graduated from the same zero, 10 cm. representing one unit of l/D. The vertical co-ordinate represents h/D in the same units. The tape is held taut by its free end and wrapped round the quadrant till it represents the desired pair of known values. Thus, if $p/D = 2$ and $c = 10$ per cent., $l/D = 2{\cdot}2$ and the tape is wrapped till the mark 22 cm. on the tape cuts the vertical line representing $p/D = 2$ units or 20 cm. The corresponding value of h is then read off on the vertical scale, $h/D = 0{\cdot}88$.

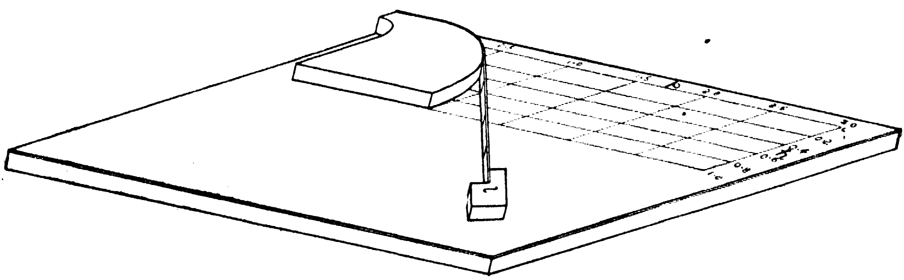


Fig. 3.

The value of θ may also be shown, by degree graduations on the disc or more accurately by a scale round the border of the board. For smaller angles, this scale is marked along a vertical line, say $p/D = 3$; for large angles, along a horizontal line such as the line $h/D = 1$. The scale is obtained from Equation (5) or (7) and may be marked, according to preference, as $\theta°$, θ radians, tan. θ or any other function. The device is most convenient and rapid in determining relations between spacings and crimps, and is equivalent to several tables between different combinations of the variables.*

For any given value of l, there is a limit to the value of θ, and of the crimp c, which may be seen by reference to Fig 1. If the cross-threads are pulled straight, h_2 becomes zero, $h_1 = D$ and from (11), the upper limit of θ_1 is given by

$$\theta_1 + \cot \theta_1 = l_1/D \quad \ldots \quad \ldots \quad \ldots \quad \ldots (17)$$

This condition is represented by the top horizontal line in Fig. 2. The cross-threads may, however, be too close to allow the full interchange of crimp and the interweaving threads will jam when the straight intermediate portion $(l_1 - D\theta_1)$ is reduced to zero. The upper limit of θ_1 is then given by

$$\theta_1 = l_1/D \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (18)$$

represented by the curve on the left boundary of Fig. 2.

In the former case, the lower limit of θ_2 is zero but in the latter it is the value which makes $h_2/D = \cos l_1/D$. This limit cannot conveniently be shown on Fig. 2, but it is of importance both in the stretching of cloth and in weaving close fabrics. If $l_1/D = \pi/2$, the equations 17 and 18 are satisfied together, the (warp) threads jam just as the cross- (weft) threads become

* Thanks for the suggestion of this device are due to Mr. D. H. Sadler of the Nautical Almanac Office.

Table I. Values of *h* in terms

$l-p$	*l* 0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6
0·001	—	·018	·023	·027	·030	·034	·037	·040	·044	·046	·047	·049	·051	·053	·055	·058
0·002	—	—	·032	·038	·043	·048	·052	·055	·060	·062	·066	·068	·071	·074	·078	·079
0·003	—	—	·038	·046	·052	·058	·063	·067	·073	·076	·080	·083	·087	·091	·094	·096
0·004	—	—	·043	·052	·060	·067	·073	·078	·083	·088	·092	·096	·100	·105	·108	·112
0·005	—	—	—	·058	·067	·074	·081	·087	·092	·098	·103	·108	·112	·117	·121	·125
0·006	—	—	—	·063	·073	·081	·089	·095	·101	·107	·113	·118	·123	·128	·132	·136
0·007	—	—	—	·067	·078	·087	·095	·102	·109	·116	·122	·127	·132	·138	·143	·148
0·008	—	—	—	·071	·083	·093	·102	·109	·116	·123	·130	·136	142	·147	·152	·158
0·009	—	—	—	·074	·087	·098	·107	·115	·123	·131	·138	·144	·150	·156	·162	·167
0·010	—	—	—	·078	·091	·103	·113	·121	·130	·138	·145	·151	·158	·164	·170	·176
0·011	—	—	—	—	·095	·107	·118	·127	·136	·144	·152	·159	·166	·172	·179	·185
0·012	—	—	—	—	·099	·112	·123	·132	·142	·151	·158	·165	·173	·180	·187	·193
0·013	—	—	—	—	·102	·116	·127	·138	·147	·156	·164	·172	·180	·187	·194	·201
0·014	—	—	—	—	·106	·120	·132	·142	·152	·162	·170	·178	·186	·194	·201	·208
0·015	—	—	—	—	·109	·123	·136	·147	·158	·167	·176	·184	·193	·201	·208	·216
0·016	—	—	—	—	·112	·127	·140	·152	·162	·172	·182	·190	·199	·207	·215	·222
0·017	—	—	—	—	·114	·131	·144	·156	·167	·177	·187	·196	·205	·213	·222	·229
0·018	—	—	—	—	·117	·134	·148	·160	·172	·182	·192	·202	·210	·219	·228	·236
0·019	—	—	—	—	·119	·137	·152	·164	·176	·187	·197	·207	·216	·225	·234	·242
0·020	—	—	—	—	·121	·140	·155	·168	·180	·192	·202	·212	·222	·231	·240	·248
0·025	—	—	—	—	—	·153	·171	·186	·200	·213	·225	·236	·247	·257	·267	·277
0·030	—	—	—	—	—	·165	·185	·202	·218	·232	·245	·258	·270	·281	·292	·302
0·035	—	—	—	—	—	·174	·197	·216	·234	·249	·264	·277	·290	·302	·314	·325
0·040	—	—	—	—	—	—	·208	·229	·248	·265	·280	·295	·309	·322	·334	·347
0·045	—	—	—	—	—	—	·218	·241	·261	·279	·296	·312	·327	·340	·354	·367
0·050	—	—	—	—	—	—	·227	·252	·274	·293	·311	·327	·343	·358	·372	·386
0·060	—	—	—	—	—	—	—	·271	·296	·318	·337	·356	·373	·390	·405	·421
0·070	—	—	—	—	—	—	—	·287	·315	·339	·361	·382	·401	·418	·436	·452
0·080	—	—	—	—	—	—	—	·300	·332	·359	·383	·405	·426	·445	·464	·481
0·090	—	—	—	—	—	—	—	—	·347	·376	·402	·426	·449	·470	·489	·508
0·10	—	—	—	—	—	—	—	—	·361	·393	·421	·446	·470	·492	·513	·534
0·11	—	—	—	—	—	—	—	—	·372	·407	·438	·465	·490	·514	·536	·557
0·12	—	—	—	—	—	—	—	—	—	·421	·453	·482	·509	·534	·557	·580
0·13	—	—	—	—	—	—	—	—	—	·433	·467	·498	·526	·553	·577	·601
0·14	—	—	—	—	—	—	—	—	—	·444	·481	·513	·543	·570	·596	·621
0·15	—	—	—	—	—	—	—	—	—	·453	·493	·527	·559	·587	·615	·640
0·16	—	—	—	—	—	—	—	—	—	—	·504	·541	·573	·604	·632	·658
0·17	—	—	—	—	—	—	—	—	—	—	·515	·553	·587	·619	·648	·676
0·18	—	—	—	—	—	—	—	—	—	—	·525	·565	·601	·634	·664	·693
0·19	—	—	—	—	—	—	—	—	—	—	·533	·576	·613	·647	·679	·709
0·20	—	—	—	—	—	—	—	—	—	—	·541	·586	·625	·661	·693	·724

Table I—continued.

$l-p$	*l* 1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	$l-p$
·20	·586	·625	661	·693	·724	·754	·781	·808	·834	·859	·883	·906	·928	·950	·972	·993	1·014	·20
·21	·596	·637	·673	·707	·739	·769	·798	·826	·852	·878	·902	·926	·949	·972	·994	1·016	1·037	·21
·22	·605	·648	·686	·721	·754	·785	·814	·842	·870	·896	·921	·946	·970	·993	1·016	1·038	—	·22
·23	·613	·658	·697	·734	·768	·799	·830	·859	·887	·914	·940	·965	·989	1·013	1·037	—	—	·23
·24	·621	·667	·708	·746	·781	·814	·845	·875	·903	·931	·958	·984	1·009	1·032	—	—	—	·24
·25	·628	·677	·719	·758	·794	·828	·860	·890	·920	·948	·975	1·002	1·027	—	—	—	—	·25
·26	·634	·685	·729	·769	·806	·841	·874	·905	·935	·964	·992	1·019	—	—	—	—	—	·26
·27	—	·693	·739	·780	·818	·854	·888	·920	·950	·980	1·009	1·036	—	—	—	—	—	·27
·28	—	·701	·748	·790	·830	·866	·901	·934	·965	·996	1·025	—	—	—	—	—	—	·28
29	—	·708	·757	·801	·841	·878	·914	·948	·980	1·011	1·041	—	—	—	—	—	—	·29
·30	—	·714	·765	·810	·852	·890	·926	·961	·994	1·02[illegible]	—	—	—	—	—	—	—	·30
·31	—	·720	·773	·820	·862	·901	·938	·974	1·008	1·040	—	—	—	—	—	—	—	·31
·32	—	·726	·781	·829	·872	·912	·950	·986	1·021	—	—	—	—	—	—	—	—	·32
·33	—	·730	·788	·837	·882	·923	·962	·999	1·034	—	—	—	—	—	—	—	—	·33
·34	—	—	·795	·845	·891	·933	·973	1·011	1·046	—	—	—	—	—	—	—	—	·34
35	—	—	·801	·853	·900	·943	·984	1·022	—	—	—	—	—	—	—	—	—	·35
·36	—	—	·807	·861	·909	·953	·994	1·034	—	—	—	—	—	—	—	—	—	·36
·37	—	—	·812	·868	·917	·963	1·005	1·045	—	—	—	—	—	—	—	—	—	·37
·38	—	—	·817	·875	·925	·972	1·015	—	—	—	—	—	—	—	—	—	—	·38
·39	—	—	·822	·881	·933	·981	1·025	—	—	—	—	—	—	—	—	—	—	·39
·40	—	—	·826	·888	·941	·989	1·034	—	—	—	—	—	—	—	—	—	—	·40
41	—	—	.829	·894	·948	·998	1·043	—	—	—	—	—	—	—	—	—	—	·41
·42	—	—	—	·899	·955	1·006	1·052	—	—	—	—	—	—	—	—	—	—	·42
·43	—	—	—	·904	·962	1·013	—	—	—	—	—	—	—	—	—	—	—	·43
·44	—	—	—	·909	·968	1·021	—	—	—	—	—	—	—	—	—	—	—	·44
·45	—	—	—	·914	·974	1·028	—	—	—	—	—	—	—	—	—	—	—	·45
·46	—	—	—	·918	·980	1·035	—	—	—	—	—	—	—	—	—	—	—	·46
·47	—	—	—	·921	·986	1·042	—	—	—	—	—	—	—	—	—	—	—	·47
·48	—	—	—	·924	·991	1·049	—	—	—	—	—	—	—	—	—	—	—	·48
·49	—	—	—	·927	.996	1·055	—	—	—	—	—	—	—	—	—	—	—	·49
50	—	—	—	·929	1·001	1·061	—	—	—	—	—	—	—	—	—	—	—	·50

straight. The former then take the form of a series of semi-circles and have the maximum possible crimp (0·5708). If $l_1/D > \pi/2$, the former limit applies, but if $< \pi/2$, the latter applies. The bearing of these limits on cloth settings is discussed more fully in Part IV. Owing to their special interest, the values of p, c and h are tabulated for the limits $l/D - \theta = 0$ and $\cot\theta$ (Table II).

Applicable Formulae.

The desired relation between p, c and h (in terms of D) is given by Fig. 2, but a graph can only be used for particular values. To pursue problems of cloth structure analytically, it is necessary to express the relation in functional form. One might at least write, $h_1 = f(p_2, c_1)$ where f is given by and may be evaluated from Fig. 2. The analyses would, however, be facilitated and made more intelligible if a simple approximate form can be found for this function. This is particularly necessary when the value of D is not known but is the object of calculation.

Such a formula was obtained by expanding the trigonometrical functions in terms of ascending powers of θ.

The expansion of Equation (11) gives

$$h_1 = l_1\theta_1 - D\theta_1^2/2 - l_1\theta_1^3/6 + D\theta_1^4/8 + \ldots \qquad (19)$$

and the expansion of Equation (10) gives

$$p_2 = l_1 - l_1.\theta_1^2/2 + D.\theta_1^3/3 + l_1.\theta_1^4/24 + \ldots \qquad (20)$$

$$\text{Hence } c_1 = \frac{l_1 - p_2}{p_2} = \frac{l_1.\theta_1^2/2 - D.\theta_1^3/3 - \ldots.}{l_1 - l.\theta_1^2/2 + D.\theta_1^3/3 + \ldots.} \quad \ldots \quad \ldots (21)$$

When θ is small, these reduce to:

$$h_1 = l_1\theta_1\,;\ p_2 = l_1\,;\ c_1 = \theta_1^2/2 \text{ and hence } h_1 = p_2\sqrt{2c_1}, \text{ approximately} \quad (22)$$

A further degree of approximation gives the form

$$h_1 = p_2\sqrt{2c_1} - Dc_1/3 + \ldots \quad \ldots \quad \ldots \quad \ldots (23)$$

When Equation (22) is compared with the tabulated values, it is found to give a close approximation at small values of c_1 and large values of p_2, but a good approximation over the range of fabric structures is made by modifying the value of the factor. The formula

$$h_1 = \frac{4}{3}.p_2\sqrt{c_1} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (24)$$

reproduces the rigorous values well enough for many purposes; only in extreme structures does the error amount to 5 per cent. and never to 10 per cent. It will be used when a simple form is needed for analytical purposes, or for reducing observations subject to errors of this order.

The specific volume, v, or volume per gram, of a cylindrical yarn is related to the diameter, d, in mils, by the formula:

$$d = 34{\cdot}14\sqrt{v}/\sqrt{N} \quad \ldots \quad \ldots (25)$$

When combined with Equations (12) and (24), this gives an approximate but very simple and applicable form of the relation between spacing (threads per inch), crimps and counts:

$$D = \frac{4}{3}(p_2\sqrt{c_1} + p_1\sqrt{c_2}) = 34{\cdot}14\,(\sqrt{v_1}/\sqrt{N_1} + \sqrt{v_2}/\sqrt{N_2}) \ldots (26)$$

Owing to the compression of threads in a fabric, the values of v in these formulae cannot be determined by visual measurements of yarn diameter, which often greatly exceed the effective diameter of the threads as they lie in the cloth. Most of the discrepancy between the mathematical assumptions and the actual form of real fabrics is due to flattening of the threads, a subject which will be discussed at a later stage, p. T67.

A better approximation to the rigorous geometry is given by Equation (23) and this again is improved by modifying the factor of Dc_1, giving the formula

$$h_1 = p_2\sqrt{2c_1} - 0.2\, Dc_1 + \delta_1 D \quad \ldots \quad \ldots \quad \ldots (27)$$

δ The residual δ is now so small that it may be read off a graph (Fig 4) to

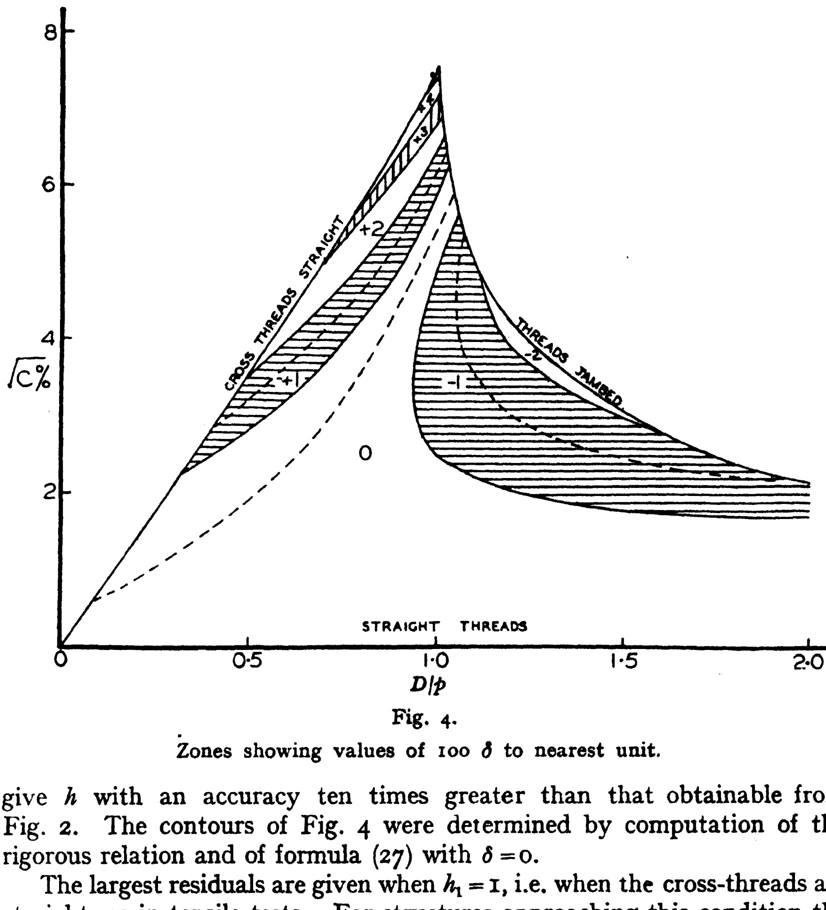


Fig. 4.

Zones showing values of 100 δ to nearest unit.

give h with an accuracy ten times greater than that obtainable from Fig. 2. The contours of Fig. 4 were determined by computation of the rigorous relation and of formula (27) with $\delta = 0$.

The largest residuals are given when $h_1 = 1$, i.e. when the cross-threads are straight, as in tensile tests. For structures approaching this condition the factor 0·1 instead of 0·2 in the second term gives a very good approximation.

In all the figures and tabulations of the rigorous relations the quantities must be expressed in units of the length D. But very often, the threads per inch and the crimps will be known from measurement and the problem will be to find the corresponding value of D.

From Equation (27) and the corresponding formula for h_2

$$D = h_1 + h_2 = (p_2\sqrt{c_1} + p_1\sqrt{c_2}) - D\,[0{\cdot}2\,(c_1 + c_2) - (\delta_1 + \delta_2)]$$

therefore

$$D = \frac{p_2\sqrt{c} + p_1\sqrt{c}}{1 + 0{\cdot}2\,(c_1 + c_2) - (\delta_1 + \delta_2)} \quad \ldots \quad \ldots \quad \ldots (28)$$

The value of the small correction $(\delta_1 + \delta_2)$ is determined by first calculating D from Equation (28) with $(\delta_1 + \delta_2) = 0$, thence calculating p_1/D and p_2/D and from them and the known values of crimp, reading off from Fig. 4 the values of δ_1 and δ_2. On substituting these in Equation (28),

the accurate value of D is obtained. The procedure could be repeated but it will usually be found that the correction of D has no appreciable effect on the values of δ. The value of D is given with an accuracy as great as that of Table I, and Equation (28) is the most useful form of the geometrical relation for the first stage of application to observations on cloth. Once D is known, the tables or model are available and more convenient than formulae.

In practically every case, the values of δ are so small that no appreciable error is introduced by using an approximation to this formula, which facilitates calculation.

$$D = \frac{\Sigma p\sqrt{c}}{1 + 0.2\,\Sigma c}.(1 + \Sigma\delta) \quad \ldots \quad \ldots \quad \ldots (28a)$$

where Σ signifies the sum of the terms referring to warp and weft.

Special Structures.

In a few particular cases, the rigorous relations take a simple form which allow direct computation. Of these, the jammed structures are of importance in relation to cloth settings and are discussed at some length in Part IV. It may suffice here to note that when the warp is jammed $l_1/D = \theta_1$ and Equations (10) and (11) simplify to

$$p_2/D = \sin l_1/D = \sin (1 + c_1)p_2/D \quad \ldots \quad \ldots (29)$$

$$\text{and } h_1/D = 1 - \cos l_1/D \quad \ldots \quad \ldots \quad \ldots \quad \ldots (30)$$

A special structure of general interest is that of the truly square cloth, with equal diameters, spacings and crimps. This condition yields two independent equations, $p_1 = p_2$ and $c_1 = c_2$, leaving two degrees of freedom, the scale D and the relative openness p/D. From any given value of the latter, the structure may be readily calculated from the equation derived from Equation (15), noting that $h_1 = h_2 = D/2$.

$$t = \tfrac{4}{3}[p/D - \sqrt{(p/D)^2 - 0{\cdot}75})] \quad \ldots \quad \ldots \quad \ldots (31)$$

In a jammed square cloth, the structure is determinate save for scale. From Equation (11), the two conditions give

$$\frac{l}{D} - \theta = (\cos\theta - 0{\cdot}5)/\sin\theta = 0\,; \quad \cos\theta = 0{\cdot}5$$

$$\theta = 60^\circ \text{ or } l/D = 1{\cdot}0472$$

$$p/D = \sin 60^\circ = 0{\cdot}866\,; \quad c = l/p - 1 = 0{\cdot}2092 = 20{\cdot}9\%.$$

It will be seen that a square cloth cannot be close, as the yarn leaves uncovered a proportion $(p - d)/p = 0{\cdot}4227$, of the total space per thread, and the proportion of space not covered by the projection of both sets of threads is $(0{\cdot}4227)^2 = 0{\cdot}1787$. Greater cover is, of course, attainable in practice by the flattening of the threads.

For square cloths of more open structure, the approximate relation, Equation (26), is useful, giving

$$c = 656\,v/Np^2 = 0{\cdot}0256\sqrt{v}.K \quad \ldots \quad \ldots \quad \ldots (32)$$

where the cover factor, K, $= 1000/p\sqrt{N}$. This gives a relation which is often useful in practice to give a rough idea of the crimp in a roughly square cloth; c per cent. $= (K/4)^2$.

When spacing and crimps are unequal, and both directions are jammed, Equations (29) and (30) apply to both directions, also

$$\cos\theta_1 + \cos\theta_2 = 1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots (33)$$

As complete cover cannot be attained with a square cloth, the case of special interest is where the threads of one direction, usually the warp, are laid in

contact so that their projections cover the plane of the cloth ($p = d$). This condition is practically attained in good poplins and canvases. The conformation is still only determinate when the ratio of the diameters (or counts) is given. If they are similar, $d_1 = d_2 = D/2$ and $p_1 = D/2 = D \sin \theta_2$; $\theta_2 = 30° = 0{\cdot}5236$; $\cos\theta_2 = 0{\cdot}866$, $\cos\theta_1 = 0{\cdot}134$, $\theta_1 = 82°18' = 1{\cdot}4364$; $p_2 = 0{\cdot}991\ D$, which is very nearly twice p_1. (Good poplins commonly have half as many picks as ends per inch.) $l_1 = D\theta_1 = 1{\cdot}4364$, $c_1 = 0{\cdot}45$; $l_2 = 0{\cdot}5236D$, $c_2 = 0{\cdot}0472$.

Actual cloths of this type show a disparity of crimps approaching these figures, some 30 per cent. being observed in the warp of close ducks. Compression of the threads, and the nice adjustment of the reed spacing necessary to attain simultaneous jamming of the two directions, would make closer approach to this limiting conformation unlikely.

These special structures illustrate the fact that three independent relations between the weave particulars are necessary and sufficient to determine the conformation, apart from the scale. In general, the relations will not be expressible so simply by the rigorous formulae, and one or other of the graphical or approximate expressions will be suitable.

Crimp Interchange.

Suppose, then, that a structure has been specified by the necessary four elements, say the threads per inch and crimps in both directions, and that all the other features have been calculated. What changes occur in the structure when the dimensions are changed? The change may be specified by a given percentage change in length or width, say in stentering, or by the attainment of a particular condition, such as the straightening of one set of threads by tension.

In a pure crimp interchange (i.e. ignoring any compression or extension of the threads themselves), three elements of the structure are invariants, viz. l_1, l_2 and D. The values of l are at once calculated from the observed spacings and crimps from Equation (9) and $D = (h_1 + h_2)$ is obtained from Equation (24) or more precisely from Equation (28a). One relation, therefore, suffices to determine the new configuration and the changes in all the other quantities or relations. The new condition may be determined by the fact that the length is increased by the ratio a, when $p' = p\ (1 + a)$, using the accent to distinguish new values. If the new condition is the straightening of the warp threads, $c'_1 = 0$; if the equalisation of crimps, $c'_1 = c'_2$.

The most general manner of solving any such problem is to plot the two points representing the original configuration of warp and weft on Fig. 2, follow these along the lines, l = constant, keeping $(h_1 + h_2) = D$, till the specified condition is attained. The same process can be performed more precisely by Table I and more expeditiously with the mechanical model.

Take, as an example of the application of these formulae, a voile on which measurements gave the figures:

Threads per inch 48/55; counts 30/29; crimps 4·5%/9·5%

From Equation (24) $h_1 = (4/3) \times (1000/55)\sqrt{0{\cdot}045} = 5{\cdot}148$ mils,

$h_2 = 8{\cdot}562$ mils, and $D = (h_1 + h_2) = 13{\cdot}710$ mils.

Using the more precise formula of Equation (28a), the first approximation gives

$$D' = \sqrt{2}.\frac{(18{\cdot}18 \times 0{\cdot}2121) + (20{\cdot}83 \times 0{\cdot}3082)}{1 + (0{\cdot}2 \times 0{\cdot}14)}$$
$$= 14{\cdot}139 \text{ mils.}$$

Then $p_2/D' = 1{\cdot}285$, $p_1/D' = 1{\cdot}473$, and from Fig. 4, $\delta_1 = -0{\cdot}003$, $\delta_2 = +0{\cdot}002$; therefore $D = 14{\cdot}12$ mils. The approximate formula is here in error by 3 per cent., which is certainly less than the probable error inherent in the observational data and which would be negligible in any practical application. The separate amplitudes can now be calculated by Equation (27), giving $h_1 = 5{\cdot}28$, $h_2 = 8{\cdot}84$ mils.

Equation (25) may be applied to see how this value for the sum of the diameters compares with the counts. If the specific volume of the two threads be the same,

$$\sqrt{v} = 14{\cdot}12/34{\cdot}14\ (1/\sqrt{30} + 1/\sqrt{29}) = 1{\cdot}123,\ v = 1{\cdot}26.$$

This is about the average value obtained by visual measurements on hard twisted threads (see footnote, p.T48) so there appears to be no distortion in the structure.

For any question of change of dimensions, the three invariants of this structure are $D = 14{\cdot}12$ mils, $l_1 = p_2\ (1 + c_1) = 19{\cdot}00$ mils, $l_2 = 22{\cdot}81$ mils; whence $l_1/D = 1{\cdot}345$, $l_2/D = 1{\cdot}614$.

From the fact that $l_2/D > \pi/2$, it is geometrically possible for the warp to be pulled straight without jamming the weft. The latter will then have a crimp of 42·6 per cent. (from Table II) and the warp spacing will be 16·00 mils (22·81/1·426). The warp crimp being zero, the weft will be spaced at 19·00 mils. Comparing these figures with those of the original cloth, the warp dimension will be increased from 18·18 to 19·00 in the proportion of its crimp, 4·5 per cent., the weft dimension decreased from 20·83 to 16·00 or 23·2 per cent. The area of the cloth is thus diminished and its weight increased by 19·6 per cent.—assuming that the threads are not extended or compressed.

Considering now the stretching of the cloth weft-way, the fact that $l_1/D < \pi/2$ means that the warp threads will be jammed before the weft becomes straight. From Table II this will occur when $c_1 = 0{\cdot}38$ or 38 per cent., $p_2/D = 0{\cdot}976$, $h_1 = 0{\cdot}776$; whence $h_2 = 0{\cdot}224$ and, from Table I, $p_1/D = 1{\cdot}598$, $c_2 = 0{\cdot}0101$ or 1·01 per cent. The weft dimension will have increased from 20·83 to 22·58 ($1{\cdot}598 \times 14{\cdot}12$) or 8·4 per cent., and the warp decreased from 18·18 to 13·78 or 24·2 per cent.

Suppose this cloth shrinks warp-way by 2 per cent., how will the width, the crimps and the thickness change? The new condition is that $p_2/D = 0{\cdot}98 \times 18{\cdot}18/14{\cdot}12 = 1{\cdot}262$. From Equation (9), the warp crimp increases to 6·58 per cent., or $c_1 = 0{\cdot}0658$. Reading from Table I or Fig. 2, the new value of h_1/D is 0·443, whence h_2/D is 0·557 and, again reading from the graph, along the line $l/D = 1{\cdot}614$, $c_2 = 0{\cdot}072$ or 7·2 per cent. and $p_1/D = 1{\cdot}505$, $p_1 = 21{\cdot}26$ mils. The weft direction therefore extends 2·06 per cent. and there is a slight increase in area consequent on the more equal distribution of crimp.

Using Equation (25), to determine the diameters of the threads, the value of $(h + d)$ is (5·28 + 6·99) or 12·27 mils for the warp threads, (8·84 + 7·11) or 15·95 mils for the weft. The latter value is therefore the thickness of the cloth (assuming it to be perfectly regular). After shrinking, these values become 13·25 and 14·98 mils, respectively. The weft still projects, but by a much smaller amount (0·86 instead of 1·84 mils on either side) and the cloth is 1 mil thinner.

The condition that the two threads should project equally is one of technical importance, as it ensures that both resist abrasive wear, produces

a smooth surface and gives the minimum thickness and is the condition that calendering tends to produce. It is easily defined by the condition:

$$G = h_1 + d_1 = h_2 + d_2 = \tfrac{1}{2}(h_1 + h_2 + d_1 + d_2) = D\ ;\ h_1 = D - d_1 \quad (34)$$

The minimum thickness, as is otherwise obvious, is the sum of the thread diameters, 14·1 mils, or 1·8 mils less than that in the state received. At minimum thickness, the values obtained from Table I are $p_2 = 1{\cdot}233D = 17{\cdot}41$ mils ($c_1 = 9{\cdot}1$ per cent.) and $p_1 = 1{\cdot}530D = 21{\cdot}62$ mils ($c_2 = 5{\cdot}5$ per cent.). The state can therefore be attained by stentering the cloth to increase the width from 20·83 to 21·62 or by 3·8 per cent.—ignoring changes in thread dimensions.

The maximum thickness is attained when one or other of the threads is straightened as far as possible. In an open cloth, where either may be straightened to zero crimp, this thickness $G_{(\max)} = D + d$, where d is the diameter of the thicker thread, and it is attained by straightening the thinner threads. As, in this case, the thinner warp can be straightened, the maximum thickness is $14{\cdot}12 + 7{\cdot}11$ mils $= 21{\cdot}23$ mils. Tapes are often wound on rods under high tension and the consequent change of thickness, which may be increase or decrease, is of material importance in relation to small clearances.

The main motive for undertaking this analysis was provided by the experimental evidence of the important influence of crimp on numerous features of practical and technical interest. In such matters, many other conditions of crimp interchange might be called for, besides the few exemplified—the condition of equal crimps, of equal inclinations (θ) or spacings of minimum weight or specific volume, maximum transparency or any balance of crimps suggested by experiments on strength, extension, compressibility, stiffness, shrinking, or permeability of all kinds.

Modes of Attack on Various Problems.

In the determination of structures with given features, the general problem may be put as follows: l_1/D and l_2/D having known constant values, it is required to solve the general equation, $f(c_1) + f(c_2) = 1$, when a particular condition defining c_1, c_2 or the relation between them is fulfilled. The function, f, involves the parameter l/D of the same suffix as c but is otherwise similar for the two variables. It is defined sufficiently by the tables, etc., given herein, from which the value $h_1/D = f(c_1)$ may be obtained for any value of c_1 and l_1.

The particular condition defining the configuration desired may take an indefinite number of forms, which depend on the character of the problem. Some cases of general interest will be considered, as they allow of analytical expression which facilitates the solution of practical problems. To save circumlocution, it will be assumed that the new condition is defined by a change in the warp.

Case 1. The warp crimp is changed to a known value c_1'. Then c_2' is given by

$$f(c_1') + f(c_2') = 1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots (35)$$

and all the other features of the structure follow from relations already given. Most of the problems reduce to this as the penultimate form.

Case 2. The warp dimension is increased in a known proportion α, $p_2' = (1+\alpha)p_2$, which reduces to $c_1' = (c_1 - \alpha)/(1+\alpha)$; or the warp is extended as far as possible, (a) till the threads are straight, (b) till the weft is jammed. Condition (a) can only occur when $l_2/D > \pi/2$; $c_1' = 0$, $\theta_2' + \cot\theta_2' = l_2/D$,

and c_2' is given by interpolation on a graph of θ and l/D plotted from the right-hand side of Table II. In condition (*b*), the weft is jammed when $l_2/D=\theta_2$, $c_2'=\theta_2/\sin\theta_2-1$ and c_1' is found from Equation (35).

Case 3. The dimensions are changed to produce a given difference of crimps, $c_1'=c_2'+a$. No simple analytical form is applicable. A graph may be drawn of c_2 against c_1 in the region around the desired condition, which may be located by any rough and convenient approximation. The formula,

$$l_1\sqrt{c_1}+l_2\sqrt{c_2}=\text{constant} \quad \ldots \quad \ldots \quad \ldots (36)$$

is such an approximation. It is an alternative form derived in the same way as Equations (22) and (26), though less exact in its reproduction of the rigorous geometry. Any relation between the crimps may thus be applied, whether it be a known value of c_1' as in Case 1, equality of crimps when $a=0$, or a condition determined by experiment. For instance, it is found that the breaking extension of cloth is roughly equal to the sum of the crimp and yarn extension; a may therefore be made equal and opposite to the difference of yarn extensions to give a cloth capable of equal extension in the two directions. Other more complex relations, such as given values of dc_2/dc_1, will be found of interest in studying cloth under stress, and values or relations of crimps may be defined by experimental relations on strength, shrinkage, water penetration, and many other physical properties.

Case 4. The condition may refer to thickness. As only the sum of the diameters is known from geometry, a relation between the specific volumes is necessary. If the two threads are similar, this may be taken as equality. If one is hard, a voile or sized thread, its value may be assumed from yarn measurements. Equation (25) then gives d_1 and d_2 separately.

The cloth thickness is the greater of the two quantities $(h+d)$. The minimum thickness, D, is produced when $h_1/D=f(c_1')=1-d_1/D$; $f(c_2')=d_1/D$. If one set of threads is closely spaced and highly crimped, say the warp, it may not be possible to realise this condition. The warp will jam the weft before its prominent crowns are reduced to the level of the weft. This happens when $h_1/D=\cos l_2/D$, when $G=d_1+D\cos l_2/D$. The maximum thickness $(D+d)$, is given by straightening the thinner threads if possible (Case 3); if not, by the greater value of $h+d$ obtained by straightening either thread as far as possible.

If the two quantities $[Df(c')+d]$ are plotted against assumed values of c, any value of thickness may be determined from the two graphs. Conditions may also be defined to make one thread project on the surface by a known amount. This projection of threads is important in questions of appearance, feel and wear—ribbed effects are enhanced, wear resistance diminished thereby. Defects may be produced in finishing by a change in thickness caused by a tight band of ends—a dark stripe may be caused by increased accessibility to dye liquor in open width dyeing or the surface finish in calendering may be affected.

Case 5. The condition is defined by a desired value of θ, the maximum inclination of the warp threads. This has particular reference to the pin-head lustre and reflection curve of poplins. When l_1 and θ_1 are known, p_2 and h_1 are given explicitly and rigorously from equations (10) and (11), hence c_1 and h_2, but c_2 must be found as usual by graphical or approximate methods.

Case 6. A given value or relation of threads per inch is defined. Particular cases are that one set of threads may be closed—the spacing

made equal to the diameter ($p_1 = d_1$); the spacings may be made equal ($p_1 = p_2$); the interstices made square ($p_1 - d_1 = p_2 - d_2$) or of maximum area. Spacing only changes slowly with crimp, so that precise values from the careful use of tables should be used. In practice, the purely geometric change may be smaller than that due to extension and compression of the threads.

Cover, or transparency, permeability to air or water, filtering action and weight are all affected by the changes in spacing due to crimp redistribution and these features influence many of the useful qualities of fabrics. They can only be discussed in detail in special treatments, as some are rather complex. Permeability of close cloths, for instance, is greatly influenced by the spaces left between the crimped threads, oblique to the plane of the cloth and not indicated by the projection of the threads thereon. A few of the simpler features are as follows:

The minimum projected dimension of interstice, of interest in filtering problems, is the smaller value of $(p - d)$.

The number of interstices per square inch is $10^6/p_1p_2$, each of dimensions $(p_1 - d_1)(p_2 - d_2)/10^6$ sq. in. The fraction of total projected area left open or transparent, $1 - C = (p_1 - d_1)(p_2 - d_2)/p_1p_2$. The area covered by projection of threads,

$$C = d_1/p_1 + d_2/p_2 - (d_1/p_1)(d_2/p_2) \quad \ldots \quad \ldots (37)$$

The weight in oz. per sq. yd., when the lengths are given in mils, is

$$W = 0{\cdot}588\,(l_1d_1^2/v_1 + l_2d_2^2/v_2)/p_1p_2 = k.D \div (p_1/D)(p_2/D) \quad \ldots (38)$$

This shows at once that, in crimp redistribution, the minimum weight is given by the maximum value of p_1p_2 or $(1+c_1)(1+c_2)$; and that, of fabrics identical in structure but differing in scale, the weight varies with the first power of the yarn diameters or as the inverse square root of the counts. Another quantity of which the minimum value may be of practical importance is the specific volume [Equation (3)].

The analytical forms of the geometrical relations are seldom useful in problems such as the determination of maximum transparency or minimum weight, which are best dealt with by plots of the pertinent quantities, as in Case 5.

Case 7. The full data of threads and crimps are known for two states of a fabric. Then two sets of values of l_1, l_2 and D are determined independently and differences therein provide data on extension and compression, which may be related to the treatment—stretching, wetting, etc.—that produced the change. This is the usual first step in practice, whence the necessary data are obtained to supplement the geometrical calculations.

Case 8. Known changes are produced in l_1, l_2 and D by swelling or otherwise. What is the effect on the structure? This is simply a generalisation of the preceding cases, where the change is assumed to be zero; and any problem needs one more relation to define it. This may be any one of the conditions already dealt with, substituting the changed values for the original ones, or it may be a statical condition, defined by tensions on the cloth.

Case 9. In all the cases given above, purely geometrical conditions have determined the configuration. Very often the practical problem is to determine the effect of forces, tensions and pressures. The statics of cloth structure is a larger subject than the geometry and the following discussion is the barest introduction to a problem which must be deferred to other communications.

The simplest case is where the two sets of threads are under known tensions, say F_1 and F_2 oz. per inch in the warp and weft directions, respectively. The tension in the plane of the cloth per warp thread is $F_1.p_1/1000$ oz., which must be balanced by the horizontal component of the tension (T_1) in the thread where it is not in contact with the weft ($T_1\cos.\theta_1$), or

$$T_1 = F_1p_1.\sec\,\theta_1/1000 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \; (39)$$

Still assuming that the threads have negligible rigidity, the vertical components of the two thread tensions must balance to maintain equilibrium at the crossing,

$$T_1\sin\,\theta_1 = T_2\sin\,\theta_2$$

$$\text{and } F_1p_1.\tan\,\theta_1 = F_2p_2.\tan\,\theta_2 \quad \ldots \quad \ldots \quad \ldots \; (40)$$

This provides the relation necessary to define the structure of cloth held by external tensions when the threads are assumed to be perfectly flexible.

Case 10. The neglect of rigidity is reasonable in open cloths under high tensions, especially when wet, but generally the shearing forces, bending moments and lateral pressures have a considerable influence on the balance of crimps. They also influence the geometry itself and introduce complexity which makes rigorous analysis impracticable, even on the simple assumptions of elastic theory. As these assumptions certainly do not describe textile materials accurately, they do not furnish a sufficient basis for the theoretical analysis of observations thereon. On the other hand, some allowance must be made for rigid resistance to bending when considering the effect of forces on cloth structure. Owing to its complexity and unsettled state, the question is deferred to a special section (p.T53, *et seq.*).

Case 11. The effect of the normal pressure of calendering may be estimated comparatively simply. It tends to force down the prominent crowns to produce the condition of minimum thickness (Case 4). A marked flattening of the threads usually accompanies the crimp interchange and some recovery from the imposed strains occurs after calendering.

Yarn extension due to tension, flattening due to pressure, and recovery from these strains after swelling, must be studied empirically. The effects that they superimpose on the geometrical changes may be estimated and predicted after experience with various fabrics under various treatments. Changes in cloth dimensions are largely the result of the different crimp balances produced by the various conditions considered above—pick length in grey cloth, minimum thickness after a calender finish, elastic balance after loose shrinkage, equilibrium of tensions in use, and combinations of these.

Finally, there remains the type of problem in which the cloth is constrained along certain lines and distorted by outside forces, whether it be in a strength tester or in use. These are the practical problems for which cloth geometry is being primarily investigated but they introduce the further and great complexity that the pattern of the weave is distorted and varies over the surface. The preceding discussion all refers to a uniform element of cloth, either a large area in an undistorted form or a unit cell of rectangular shape. It may be applied to particular portions of cloth under stress, for instance, the middle of a strip under tensile test or the centre of the specimen in a bursting test. Changes of shape and statical relations in a finite area of cloth under compound stresses may best be dealt with by the methods of differential geometry, taking the warp and weft threads themselves as co-ordinates.

PART III

DEVIATIONS FROM THE SIMPLE GEOMETRY

Compression of Threads.

The distortion of a thread of twisted fibres by pressure against another is so different from that of a circular cylinder of homogeneous elastic material that there is no point in developing the difficult mathematics of the latter conception. On the other hand, the distortion is much too great in most fabrics to ignore and must be considered by empirical methods.

Adopting, from the previous analysis, the deduction that the displacement of a thread normal to the cloth plane is $\frac{4}{3}\,p\sqrt{c}$, the sum of the smaller or
b normal diameters (b) of the two flattened threads is given by

$$b_1+b_2=\tfrac{4}{3}(p_2\sqrt{c_1}+p_1\sqrt{c_2}) \quad \ldots \quad \ldots \quad \ldots (41)$$

The compressed thread may be considered to have the form of an ellipse
a in cross-section, with an area $ab\pi/4$, where a and b are the major and minor axes. This expression for the area is a good approximation for forms roughly resembling ellipses and is probably good enough for all practical purposes. If d be retained as the symbol for the diameter of the circular thread of the same cross-sectional area, we have, as in Equation (25),

$$d_1=\sqrt{a_1b_1}=34{\cdot}14\sqrt{v_1/N_1} \quad \ldots \quad \ldots \quad \ldots (42)$$

To make the problem determinate, further extraneous data are necessary to define the relative ellipticity of the two threads when pressed against one another. Suppose $e_1=e_2/\alpha$, where $e=\sqrt{b/a}$, and α is known. Then

$$\begin{aligned}\tfrac{4}{3}(p_2\sqrt{c_1}+p_1\sqrt{c_2})&=34{\cdot}14\ (e_1\sqrt{v_1/N_1}+e_2\sqrt{v_2/N_2})\\ &=34{\cdot}14\ e_1\ (\sqrt{v_1/N_1}+\alpha\sqrt{v_2/N_2}) \ldots \quad \ldots (43)\end{aligned}$$

Though the apparent specific volume of a free thread varies considerably with twist, fibre, treatment and method of measurement, it appears and it is probable that, in a fabric, all cotton threads are compressed to a fairly constant specific volume which is that of hard, round threads, about 1·1. Rounding off the constant obtained by assuming this value, we obtain

$$\begin{aligned}\tfrac{4}{3}(p_2\sqrt{c_1}+p_1\sqrt{c_2})&=36\ e_1\{(1/\sqrt{N_1})+(\alpha/\sqrt{N_2})\}\\ &\text{or } 36\ e\{(1/\sqrt{N_1})+(1/\sqrt{N_2})\} \quad \ldots (44)\end{aligned}$$

in those cases where it is sufficient to ignore any difference in the flattening of the threads. In other cases α may be determinate enough from general experience or by measurement of width of threads under mutual pressure. In the extreme case of a hard warp and soft weft, as in a grey limbric, e_1 may be taken as unity and the right-hand side becomes $36\{(1/\sqrt{N})+(e_2/\sqrt{N_2})\}$. Equation (44) is probably the most widely applicable of the results of this paper and is little affected by the great simplification of actuality which the formal assumptions represent. It may be noted that the flattening of the threads affects the form of the axis in a manner somewhat similar to rigid resistance, which, if anything, improves the validity of Equation (24), (see p.T75).

It would be laborious rather than difficult to analyse the formal relations for elliptic sections, and their practical application would be clumsy and probably no more effective in the study of actual cloth data than the approximate treatment of thread-flattening given here.

Assuming elliptic sections, the equations analogous to Equations (10)-(12) become :—

$$p_2 = (l_1 - Z_1)\cos\theta_1 + 2X_1 \quad \ldots \quad (10a)$$

$$h_1 = (l_1 - Z_1)\sin\theta_1 + D - 2Y \quad \ldots \quad (11a)$$

$$h_1 + h_2 = D = b_1 + b_2 \ldots \quad \ldots \quad (12a)$$

where

$$X_1 = \sin\theta_1\ [b_1 + \frac{b_2}{e_2}{}_2\sqrt{1 - k_2^2\cos^2\theta_1}]$$

$$Y_1 = \cos\theta_1\ [b_1 + b_2e_2^2/\sqrt{1 - k_2^2\cos^2\theta_1}]$$

$$Z_1/2 = b_1\theta_1 + \frac{b_2}{e_2}{}_2[E_1 - E(\frac{\pi}{2} - \theta_1) + k_2^2\sin\theta_1.\cos\theta_1/\sqrt{1 - k_2^2\cos^2\theta_1}];$$

$e^2 = b/a$, $k^2 = 1 - e^4$ and E is the elliptic integral of the second kind with parameter k. These formulae reduce directly to the forms for circular threads, when $e = 1$, $k = 0$, $b = d$ for both threads.

It is not practicable to tabulate the relations for the infinite variations of structure of elliptical threads, but it is comparatively easy to apply these equations to threads of known form, in order to evaluate the error involved in the treatment adopted here if the sections are really elliptical.

A mechanical model, with a deformable ring or replaceable sector in place of the circular quadrant, would allow analysis of the relations for elliptical or other forms of cross-section. No such finesse is justified at the present stage of the development of the subject, if it ever could be in face of the degree of experimental accuracy possible and of the indefinable, and rather unimportant, variations in the precise shape of the thread axis and sections. The present treatment yields a simple basis of comparison and a representation as true as the applications demand.

The flattening of the threads is particularly important in questions of cover. In the geometry of circular threads, the maximum cover is obtained by setting one set of threads so close that they touch as they cross the central plane. At the crowns along the line of a cross-thread the raised threads will then still be separated by a distance equal to their own diameter. That much better cover than this is attainable is evident on examining, for instance, a good limbric and the use of very soft, even twistless, weft to obtain good cover is well known.

The proportion of the cloth plane covered by the projection of a set of parallel circular threads is given by

$$d/p = 34{\cdot}14\frac{\sqrt{v}}{p}.\sqrt{N} = 0{\cdot}03414\sqrt{v}.K \ldots \quad \ldots (45)$$

where K is the cover factor. When $v = 1{\cdot}1$, this proportion is $0{\cdot}0358K$ or $K/27{\cdot}93$. Thus, a cover factor of 28 or more demands a lateral compression of the threads or a piling thereof in more than one layer, as in close weft sateens. The proportion of area covered by raisers along a line of cross-threads is therefore $K/56$, when the threads are circular. If they are flattened, $d = e.a.$ and the proportion covered by the projection is

$$a/p = K/28e \quad \ldots \quad \ldots \quad \ldots (46)$$

and that covered by raisers is $K/56e$.

Thus a cloth with a cover factor of 28 in the weft would have its faces fully covered thereby if e were 0·5, and b/a 0·25.

In practical application the usual procedure is to measure the threads, crimps and counts and to calculate from them the effective values of D, l_1 and l_2. These values then furnish information on the physical behaviour of the threads, their compression and changes thereof and their extension. This physical behaviour is not directly or essentially connected with the cloth structure and may be amenable to simple generalisation. It may be that changes are negligible or are related to counts, twists or other measurable features. The reverse process of calculation of structures as given in the geometrical analysis is then possible, as the changes in D and l may be estimated from rules derived from the study of the effects of the treatment—free shrinkage, calendering, stretching, etc.

A very simple example of a common application may explain this process further. Suppose a cloth shrinks s per cent. and that the percentage crimps of the thread before and after are c_0 per cent. and c per cent. Then from Equation (9), $l_0 = p_0\dfrac{(100+c_0\%)}{100}$, $l = p\dfrac{(100+c\%)}{100}$,

and $$p = p_0\frac{(100 - s\%)}{100}$$

Then the shrinkage of the yarn

$$s_y\% = 100\ (l - l_0)/l_0 = (100 - s\%)\cdot\frac{100+c\%}{100+c_0\%} - 100 \quad \ldots (47)$$

Thus the physical change, the contraction of the yarn, is separated from the more purely geometrical factor in the shrinkage, the change of crimp.

It has been found that yarn shrinkage is almost entirely confined to the first of a series of washing treatments. In later shrinkages, l may therefore be assumed constant and the crimp estimated from measurements of shrinkage by the relation

$$\frac{100+c\%}{100} = \frac{100+c_0\%}{100 - s\%}$$

From the cloth dimensions and crimps of both warp and weft a similar process applied to Equation (44) gives the values and changes in e, the flattening of the threads, and so isolates the third main factor in shrinkage, the balance of crimps or of the forces normal to the cloth plane due to external tension and rigidity. The interpretation of shrinkage tests is thus greatly enriched.

The evaluation, from spacings and crimps, of the effective diameter of the threads is particularly applicable to finished fabrics. A main effect of calendering or ironing is to flatten the crowns of threads projecting from the surface ; shrinking or other wet process reverses this effect. In calendering, the compressive forces are different from those caused by tension, which are mutual pressures between the threads combined with a constrictive force tending to maintain circularity of section. The pressure of plane surfaces on the faces of the cloth acts directly on the projecting crowns, generally all warp or weft, and only indirectly on the other threads.

On swelling, the tensions developed in the fibres of a twisted yarn produce a tendency towards the circular section, so that the flattening of threads represents an enhancement of the tendency to shrink. The balance of crimp also changes towards that determined by the rigidity of the threads, discussed in a later section. In the swollen state D is increased and l decreased, both changes diminishing p or the superficial dimensions in a calculable degree. On drying, D diminishes and l increases but, in the absence of external tension, the extra length is more easily accommodated by slack interweaving than by an increase in external dimensions. This appears in structural analysis as an increase in D or in v.

As a general rule it appears to offer the simplest way of interpreting geometrical analysis to assume a constant specific volume, $v = 1{\cdot}1$. Even if the threads do really increase in volume they are at once compressed by the first tension or pressure. After free shrinkage, Equation (44) may therefore give values of e exceeding unity. It would, of course, be false to apply such a value to questions of cover by Equation (46). The most suitable manner of dealing with such over-shrunk structures is to assume e as unity in

Equation (44) and to take the difference between the two sides of the equation as a measure of empty space between the threads at the intersections. It is then easy to calculate the increase in p necessary to take up the slackness, which is represented by a considerable extension under very low tension, found in over-shrunk fabric. Any structure yielding a value of e exceeding unity is in a slack and unstable stage ; in technical work and in testing procedure, free shrinkage should be followed by sufficient pressure or tension to ensure effective contact of the interweaving threads.

The separation of the several factors of independent nature—crimp balance, thread flattening and extension—is essential to a fundamental analysis of cloth behaviour and is made possible by the mathematical analysis, though in the final application little dependence is placed on the formal simple assumptions from which the mathematics proceed.

Another feature of the application of mathematics to experiment needs attention. The values entered into equations are the results of tests, obtained by methods on which physical practicability imposes some limitation. The observations may be intended to measure some geometrical feature but are not necessarily identical therewith. Crimp in particular is measured by removing and straightening threads, not by integrating the length of the axis *in situ* as in the mathematics. It has been found that a tension of one hank weight gives a fairly accurate result in general but error may be introduced by excessive extensibility or by strong setting of the crimp. In some heavy fabrics, indeed, it is hard even to define the crimp or the location of the yarn axes, as the threads are indented rather than bent. They may also deviate in the cloth plane, increasing the crimp without a corresponding increase in normal displacement.

Another feature to be kept in mind is irregularity. Observations usually give mean values, but the mean of a function is not always equal to the function of the mean of the variable. Thus the mean of $\sqrt{c}$ taken over a number of weave repeats is not the same as $\sqrt{\bar{c}}$, where $\bar{c}$ is the mean crimp, but is a little less. There may also be some fitting together of irregularities to enhance close packing, as this tends to relieve internal stress. The effects are probably not large and seem incalculable but their tendency is to increase the apparent flattening of the threads. Geometrical quantities derived by introducing observations on complex objects into deductions from simple mathematical assumptions must be regarded as " effective " values and interpreted with due regard to the physical complexity.

Twills and Matt Weaves.

When floats over several cross-threads occur the thread is subjected to asymmetric pressures which tend to displace its axis locally from the plane of its general path. The vertical pressures and displacements also vary with the position of the intersection relative to the weave pattern. These distortions from a simple geometric form are indefinitely variable with the weave and the physical properties of the yarn and cannot be allowed for in a simple geometry. As they have a material influence on the close packing and crimps of threads in twills and sateens, the following geometry of the simplified structure must be applied with even more caution than that of plain weaves.

Consider first twill weaves, in which every thread is separated from its neighbours at some point in the repeat. It will be assumed that the

projections of the threads on the cloth plane remain straight and orthogonal, and hence that the spacing under floats and at crossings is uniform ; further, that the vertical displacements at intersections of warp and weft threads are uniform, varying only in sign according to the face of the cloth on which each thread lies. This further assumption can be regarded as reasonable only for symmetrical twill or matt weaves such as 2×2 for which the present analysis is hardly less reasonable than is that of plain weaves.

At a spacing in which the threads cross to the other face the same relations hold as in the plane weave ; at float spaces, the yarn axis is a horizontal straight line. If the values at crossings are denoted by single accents and those in floats by double accents, and if there are f_2 cross-threads per float of each warp end ;

$$p_2 = p_2' = p_2'' = l_1'' \; ; \;\; \theta'' = 0 \; ;$$

$$c_1 = \frac{l_1' + (f_2 - 1)\, l_1''}{f_2 p_2} - 1 = (l_1'/p_2 - 1)/f_2 \qquad \ldots (48)$$

$$p_2 = (l_1' - D\theta_1').\cos\theta_1' + D\sin\theta_1' = l_1'' \qquad \ldots (49)$$

$$h_1 = (l_1' - D\theta_1).\sin\theta_1' + D\,(1 - \cos\theta_1') \qquad \ldots (50)$$

The relations between p_2, h_1 and $f_2 c_1$ are therefore identical with those between p_2, h_1 and c_1 for the plain weave and the same formulae, graphs and tables may be used.

Consider now a matt weave, in which threads continue to run parallel if together in any float. There are two spacings, of which that under floats, p'', is generally less than that at intersections, p', as no cross-threads interpose between the neighbouring parallel threads. In any repeat weft-way, there are $(f_2 - 1)$ spacings of p_2'' to one of p_2' and the mean spacing, $p_2 = \dfrac{p_2' + (f_2 - 1)\,p_2''}{f_2}$. The plain weave relations hold for the quantities singly accented and $h_1' + h_2' = D$. The mean length per cross-thread, $l_1 = \dfrac{l_1' + (f_2 - 1)p_2''}{f_2}$ and the over-all crimp, $c_1 = \dfrac{l_1 - p_2}{p_2} = \dfrac{l_1' - p_2'}{p_2' + (f_2 - 1)p_2''}$.

Separate measurements of p' and p'' are necessary to evaluate the effective yarn diameters or perform other analyses similar to those discussed for plain cloths. The lateral distortions of the threads in a twill weave cause a difference between the spacings at intersections and floats, so that a better estimate of geometrical features could be made by measuring these spacings separately. In close settings, p'' often approximates to d and their equality may usefully be assumed to determine p' from observations of the over-all threads per inch.

The analogue of Equation (40) may be obtained by considering the cell of a matt weave in which f_1 warp threads intersect f_2 weft threads. Balancing the vertical components of the tensions

$$f_1 T_1'.\sin\theta_1' = f_2 T_2' \sin\theta_2' \; ; \;\; T_1'' = T_1' \cos\theta_1' = F_1\, p_1/1000$$

$$\text{and } f_1 F_1 p_1.\tan\theta_1' = f_2 F_2 p_2.\tan\theta_1' \qquad \ldots \quad \ldots \quad \ldots \quad \ldots (51)$$

In unsymmetrical weaves of varying lengths of float, geometrical features of practical importance arise from the differences between vertical displacements under long and short floats and between the faces. These have statical effects, causing curling and other asymmetric effects of tension. It appears desirable to establish the methods of geometrical analysis in simpler fabrics before dealing with such questions.

The Crimped Form of an Elastic Thread.

It is not seriously suggested that the assumption of perfectly elastic isotropic material describes actual textile threads. The latter do, however, possess rigidity and their resistance to bending influences the form of the thread in a fabric to some extent and undoubtedly has a big effect on the balance of crimps. However far the actual elastic behaviour deviates from simple elastic theory, it still must be considered mathematically on the basis of that theory, modified by such estimation of the effect of the deviations as is possible. For instance, if the stress in each portion were initially in accordance with simple theory but fell off proportionally with time, the balance of crimps in a cloth under no external tension would remain in equilibrium ; but the effect of an external tension would increase.

In actual fabrics almost any balance of crimps geometrically possible may be stabilised by suitable treatment but the balance produced on the assumption of perfect elasticity may be regarded as a norm or basis of comparison, and the relations with spacing and counts may suggest suitable forms for expressing observed data.

It is assumed that the threads are circular cylinders, in which the bending moment is proportional to the curvature of the axis. Let m be the bending moment for unit radius of curvature.

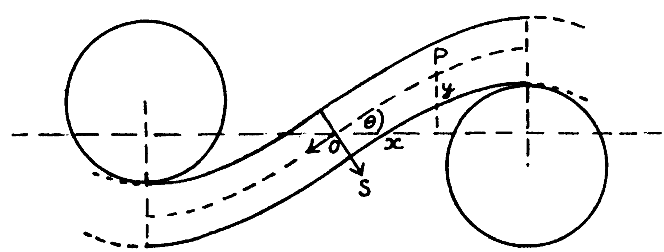


Fig. 5a

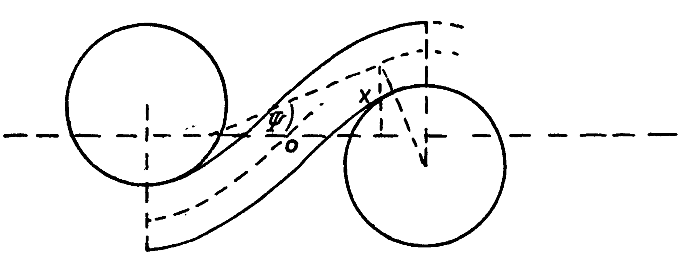


Fig. 5b

In Fig. 5a, the thread shown in section (say, the warp end) only touches the cross-thread (weft) at the point of intersection, which means that its curvature nowhere exceeds $2/D$ (Case *a*). In Fig. 5b, it is forced into contact for a finite distance, over which it is constrained to the curvature $2/D$ (Case *b*).

By symmetry, there is zero curvature and therefore zero bending moment at the mid-point O. The forces here may be expressed as a tension, $-T$, and a shearing force, $-S$. These may be resolved as a horizontal force ($-U = -T\cos\theta + S\sin\theta$) and a vertical force ($-V = -T\sin\theta - S\cos\theta$).

Then at any point P (x, y) on the axis between O and the point of contact with the weft, the bending moment

$$m.d\psi/ds = -Vx + Uy \quad \ldots \quad (52)$$

which, on substituting $ds = dx/\cos\psi$ and differentiating with respect to x, gives

$$d^2\psi/dx^2 + (d\psi/dx)^2 \tan\psi - U/m.\sin\psi + V/m.\cos\psi = 0 \quad \ldots \quad (53)$$

For any use to which this analysis will be put, it does not appear necessary to pursue this general case and complicated equation. When the external force is considerable, the form approaches that of a flexible thread and the rigidity may be ignored. The special features introduced by rigidity may best be found in the case when the external tension on the cloth is zero. Then the horizontal component U vanishes and $T = S \tan\theta$. The whole force on the section through O may be represented by V and

$$\cos\psi.d\psi = -V/m.\,x\,dx.$$

On integrating, this gives the simplified equation

$$\sin\psi = \sin\theta - V/2m.\,x^2 \quad \ldots \quad (54)$$

The distance along the axis of the yarn

$$= \sqrt{\frac{m}{2V}} \int_\theta^\psi \frac{d\psi}{\sqrt{\sin\theta - \sin\psi}}$$

$$= \sqrt{\frac{m}{V}}[F - F(\chi)] \quad \ldots \quad (55)$$

where F is the complete, $F(\chi)$ the incomplete elliptic integral of the first kind, with modulus $k = \sin\left(\frac{\theta}{2} + \frac{\pi}{4}\right)$ and $\sin\chi = \frac{1}{k}.\sin(\psi/2 + \pi/4)$.

The height of P above the central plane of the cloth

$$y = \sqrt{\frac{m}{2V}} \int_\theta^\psi \frac{\sin\psi.\,d\psi}{\sqrt{\sin\theta - \sin\psi}}$$

$$= \sqrt{\frac{m}{V}}\left[\left\{F - 2E\right\} - \left\{F(\chi) - 2E(\chi)\right\}\right] \quad \ldots \quad (56)$$

where E is the elliptic integral of the second kind.

The form of the curve is given by Equations (56) and (57) as the latter gives

$$x = \sqrt{\frac{2m}{V}}.\sqrt{\sin\theta - \sin\psi} = \sqrt{\frac{m}{V}}.2k\cos\chi \quad \ldots \quad (57)$$

To determine the values at the apex A, it is necessary to distinguish the two cases illustrated in Figs. 5a and 5b. From Equation (52), second order contact is just made at the apex when

$$2/D = V/m.\,p/2 \quad \ldots \quad (58)$$

If $\sqrt{p/D} < 2/D.\sqrt{\frac{m}{V}}$, the curvature due to the bending moment does not attain the value $2/D$ even at the apex and there is no second order contact. [Case (a).]

If $\sqrt{p/D} > 2/D.\sqrt{\frac{m}{V}}$, second order contact is made when $x = X = \frac{2m}{VD}$. [Case (b).]

Case (*a*). Values at the apex are given by

$$\psi = 0, \quad \sin\chi = 1/\sqrt{2}.k, \quad \sin\theta = Vp^2/8m \quad \ldots \quad (59)$$

whence $\sqrt{m/V} = p/2 \div \sqrt{2\sin\theta}$ ... (60)

and $h/D = p/D\left[\left\{F - 2E\right\} - \left\{F(\chi) - 2E(\chi)\right\}\right] \div \sqrt{2\sin\theta}$ ... (61)

$l = p\,[F - F(\chi)] \div \sqrt{\sin 2\theta}$,

whence $c = l/p - 1$ ... (62)

When second-order contact is made for a finite distance [Case (b)], the form of the thread approaches that of a flexible thread and so Case (a) is of more interest for the present purpose, though it probably does not occur in actual fabrics. A short table of values for intervals of θ is given in Table III.

Table III.

$\theta°$	$2\sin\theta$	$\chi°$	$F - F(\chi)$	$2E - E(\chi)$	h/p	c
10	0·3473	67·38	0·5942	0·5250	0·1174	0·0083
20	0·6840	59·68	0·8547	0·6582	0·2376	0·0335
30	1·0000	54·73	1·0782	0·7114	0·3668	0·0782
40	1·2856	51·28	1·3009	0·7214	0·5111	0·1473
49·07	1·511	49·00	1·5210	0·7080	0·6618	0·2373

The last line represents the limiting configuration of Case (a), when second order contact is just made as the cross-threads become straight. Second-order contact is always made in a structure with a greater value of θ or c, or of the spacing p/D.

(From Equations (55) and (57), $p/D = 2 \sin\theta$ when second order contact is just made at the apex.)

The crimp in a flexible thread when $p/D = 1{\cdot}511$ and $h/D = 1$ is 22·8 per cent. against the 23·7 per cent. in the rigid thread. This excess length of $\frac{9}{10}$ per cent., due to resistance to bending, even in this extreme case, is practically negligible in regard to geometrical form, for which it is evident that the assumption of flexibility is sufficiently accurate for practical purposes. The approximate formula, Equation (24), makes the crimp 24·6 per cent.

A plot of the figures in Table III shows that $\sqrt{c}$ is nearly proportional to θ, $\sqrt{c} = 0{\cdot}55\ \theta$ (radians). For rough approximations $\sqrt{c}$ may also be taken as proportional to either $\sin\theta$ or $\tan\theta$ when the angle is small.

Case (*b*). Equation (51) holds till $x = X = \frac{2m}{D^2V}$, where, if Ψ be the value of ψ at this point

$$\sin\Psi = \sin\theta - X/D \qquad (63)$$

while, from geometry, $$\sin\Psi = \frac{p-2X}{D} \qquad (64)$$

and therefore $$\sin\theta = \frac{p-X}{D} \qquad (65)$$

If Y be the value of y, X that of χ when $x = X$,

$$h/2D = Y/D + 1 - \cos\Psi \qquad (66)$$

$$l/D = \Psi + \frac{2}{D}\cdot\sqrt{\frac{m}{V}}\cdot[F - F(X)] \qquad (67)$$

and $$c = D/p\left\{\sqrt{\frac{2X}{D}}[F - F(\chi)] + \Psi\right\} - 1 \qquad (68)$$

All these quantities are expressed explicitly as functions of p and X; evaluation from other pairs of known values must be made by interpolation.

As regards geometrical form, the main object of this analysis is to check the relation between p, c and h. A plot of the values in Table III shows that the relation for Case (*a*) is very well expressed by Equation (24) which is the most suitable practical expression of the relation for flexible threads. Case (*b*) gives forms intermediate between these two and there seems no purpose in tabulating values of the above quantities.

As for flexible threads, the possible structures are limited on the one side by jamming of the threads, on the other by the straightening of the cross-threads. At the former limit, the structures are identical with those of flexible threads. For any given value of crimp over 23·7 per cent., Case (*b*) holds as the spacing is increased till the cross-threads become straight, at the structure determined by making $h = D$ in Equation (66). For smaller crimps, Case (*b*) holds till p/D attains the value ($2 \sin\theta$) as given by Equation (62) when Case (*a*) holds till $h = D$, i.e. till p/D attains the inverse of the value of h/p given in Table III. The value of c at the limiting structure with a given high value of p/D is some 0·01 (1 per cent. crimp) greater for rigid than for flexible threads, the difference decreasing to zero for the jammed structure with $p/D = 1$. For precise calculations on open structures under no tension, some consideration of rigid resistance might be justified.

Ordinarily, the only important effect of rigidity is the mutual resistance of the threads to bending and this is of predominant influence on the balance of crimps, especially when external tension is low. In the absence of external tension and pressure, the vertical forces in warp and weft must balance,

or $V_1 = V_2$. A simple expression for V is given by the analysis of Case (a) in Equation (59).

$$V_1 = m_1.2 \sin \theta_1/(p_2/2)^2 \ldots \qquad \ldots \qquad \ldots \qquad \ldots (69)$$

whence balance is given by

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{m_2}{m_1}\left(\frac{p_2}{p_1}\right)^2 \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots (70)$$

As θ is a function of c, this expression may be reduced to a form suitable for use with the ordinary quantities of fabric analysis. Considering the practical application, it is sufficient to use the very simple though rough approximation:

$$\sin \theta_1 = 1{\cdot}75\sqrt{c_1} \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots (71)$$

and therefore

$$V_1 = 14.m_1\sqrt{c_1}/p_2^2 \ldots \qquad \ldots \qquad \ldots \qquad \ldots (72)$$

The balance of rigid resistances then gives a ratio of crimps

$$c_1/c_2 = (p_2/p_1)^4.(m_2/m_1)^2 \qquad \ldots \qquad \ldots \qquad \ldots (73)$$

It seems surprising that the crimps should vary inversely with the fourth power of the spacings of similar warp and weft threads, but in fact the disparity of crimps is very large when the spacings of warp and weft differ considerably (see p.191 *et seq.*).

Though the actual balance of crimps in a fabric is almost entirely controllable, within the limitations of space, by the previous history of tensions, etc., Equation (73) is useful as a guide to the balance towards which the cloth tends when external forces and influences are relaxed, as in shrinking. This normal structure may be defined by combining Equations (26) and (73), which give

$$\sqrt{c_1}\left[\frac{m_1p_1^3+m_2p_2^3}{m_2p_2^2}\right] = \frac{3D}{4} \qquad \ldots \qquad \ldots (74)$$

The "normal" balance is derived from the case in which there is no second-order contact. It evidently cannot apply when one set of threads becomes jammed. The forces between jammed threads may be assumed of a higher order than those resisting bending in a thread free to bend. If, therefore, the above formula or Equation 40 or any other formula for the balance of crimps gives a value of crimp exceeding the limit corresponding to the spacing as shown in Table II or Fig. 2, this limiting value must be assumed and the other crimp becomes determinate geometrically.

In considering the balance of crimps determined both by external tension and rigidity, rough approximation is again justified to find a suitable way of allowing for the latter in Equation (40). It seems sufficient to add the above value of vertical force (Equation 69) to the vertical component of the tension equilibrating the external tension, giving

$$(F_1p_1+8 \cos \theta_1.m_1/p_2^2) \tan \theta_1 = (F_2p_2+8 \cos \theta_2.m_2/p_1^2) \tan \theta_2 \ldots (75)$$

where F, p and m are in units of oz. and inches, or other consistent units. If θ is small enough or the accuracy low enough, $\cos \theta$ may be taken as unity or constant and the effect of rigid resistance allowed for by an addition of the form (m_1/p_2^2) to the external tension per thread on the cloth.

The rigidity of the thread, m, depends on the material and on the diameter, assuming the form of a circular cylinder. For a coherent isotropic material

$$m = q\, s^2/4\pi \qquad \ldots \qquad \ldots \qquad \ldots (76)$$

where q is the Young's modulus, s the cross-sectional area. In this case m varies as $1/N^2$, which would apply to wires and, to varying degrees of approximation, to very hard, sized or impregnated threads.

If, on the other hand, the thread may be regarded as a mere aggregate of separate parallel filaments of number n, then

$$m = n.q.\ (s/n)^2/4\pi \quad \ldots \quad \ldots \quad \ldots \quad \ldots \ (77)$$

where s is the total area of actual material. For similar aggregates of similar filaments, differing only in the number n, the rigidity m varies with n or with $1/N$. This would apply to soft yarns, particularly to continuous filament yarns of very low twist. The rigidity of a coherent thread is n times that of an aggregate of the same fibres, so that the rigidity of a series of yarns of similar fibres varying in degree of coherence might be expressed in the form:

$$m = g\,N^{-a} \ldots \quad \ldots \quad \ldots \quad \ldots \ (78)$$

where a is a function of g and both vary with twist, sizing, staple, etc.

This discussion on flexural rigidity should not be regarded in the same way as the more purely mathematical deductions of the earlier portions of the paper. Rigour has been freely sacrificed to obtain simple and rough approximations to the effect of very complex physical phenomena, which may often only be a small correction. The treatment is justified only if the forms of the relations obtained prove useful in co-ordinating experimental data.

PART IV

PRACTICAL ILLUSTRATIONS AND EXAMPLES

Cover Factors in Commercial Fabrics.

Published data on cloth constructions rarely give the crimps of the threads, so that few of the geometrical relations can be checked on them. It is, however, useful to re-express the usual particulars—threads per inch and counts—in the system of quantities suggested here, in particular as cover factors. Similarities and differences of construction are then seen more clearly, disentangled from mere difference of scale; the type of cloth may be judged more easily and fabrics may be classified for purposes of nomenclature or definition. The cover factors allow a more simple, general and consistent specification of a type of cloth, which may vary in weight, than particular combinations of threads per inch and counts, just as the twist factor distinguishes doubling weft, weft, twist, voile and crepe yarns for all counts.

Many lists of cloth structures are given in the literature and hundreds of examples might be taken from the records of the Shirley Institute, but the first requirement in the use of the cover factor is to gain familiarity with the appearance, feel and general type in terms of this quantity. It should be worked out for familiar fabrics actually in hand, and the nearest approach to this in publication is to refer to samples available both to reader and writer. A set of such is given in Hough's "Cotton Fabrics" and the particulars there given for plain cloths are expressed in the new system of quantities in Table IV.

Where two lines are given to one cloth, they generally refer to the lower and upper limits of a range in quality.

In many cases, the particulars given in Hough's book refer to the limits of a class of fabrics and not necessarily to the illustrative cutting, but still these give a good idea of the significance of different values of cover factor. The lowest values are for the most open muslin, $5{\cdot}4 \times 5{\cdot}4$. Threads may be

Table IV.

Construction of Cotton Fabrics, in Geometrical Quantities.

$d_1 = 36/\sqrt{N_1}$ mils, where N_1 is the warp count : $\beta = \sqrt{N_1/N_2}$
$K = t/\sqrt{N}$, where t is threads per inch – K_1 warp, K_2 weft.

Name.	d_1	β	$K_1 \times K_2$		Name.	d_1	β	$K_1 \times K_2$	
Casement ...	6·8	1·25	9·1	14·1	Shirting ...	6·4	0·80	11·3	9·1
Voile	5·1	1·00	8·2	8·2	,, ...	6·4	0·89	13·4	12·0
Tussore ...	6·0	0·97	17·3	17·5	Croydon ...	6·0	1·41	7·8	11·3
Madapolam ...	5·1	1·00	11·9	10·2	Mexican ...	9·0	0·89	13·0	11·6
,, ...	4·6	1·00	12·4	10·3	,, ...	8·1	0·82	11·6	9·5
Molletan ...	7·1	2·08	8·6	13·1	Tent duck ...	9·9	1·05	13·7	14·4
,, ...	6·4	1·79	8·8	19·0	Army duck ...	18·0	0·67	22·0	9·7
Tanjib ...	6·4	0·90	8·5	7·6	Domestic ...	8·5	0·71	13·2	9·3
,, ...	6·4	0·90	9·9	8·9	,, ...	7·4	0·78	13·1	10·1
Burnley printer	6·0	0·93	12·0	9·6	Baft	9·0	0·89	14·0	15·2
Wigan ...	6·4	1·30	9·9	14·7	,, ...	8·1	0·79	12·5	12·0
,, ...	6·8	1·25	8·7	15·8	,, ...	6·0	0·97	9·3	7·1
Mull	4·6	1·00	8·3	8·3	Batiste ...	5·7	0·93	8·5	7·1
,, ...	3·6	1·00	8·0	8·0	,, ...	5·1	1·00	13·6	13·9
Lawn	6·0	0·97	12·0	11·7	Jaganath ...	8·1	1·12	9·8	9·0
Muslin ...	4·0	1·00	5·4	5·4	,, ...	7·1	1·27	9·8	11·0
,, ...	3·6	1·00	9·6	8·4	Poplin ...	6·1	1·08	22·0	5·5
T Cloth ...	9·0	1·00	10·0	10·0	,, ...	6·1	1·08	27·1	10·2
,, ...	8·1	1·00	12·5	12·5	Moreen ...	10·4	0·56	12·7	12·7
Longcloth ...	6·0	0·97	12·0	11·7	,, ...	11·4	0·48	13·9	16·6
Cheese cloth ...	5·7	1·05	8·2	7·3	Imitation repp	7·4	1·41	12·3	13·3
Bramante ...	6·4	0·90	14·2	12·6	,, ...	6·0	1·41	13·3	15·1
Organdie ...	4·6	1·00	9·8	8·8	Pongee ...	4·6	0·71	16·5	6·6
Java super ...	9·0	0·82	15·0	11·4	,, ...	6·2	1·03	10·3	10·6
Cambric ...	4·6	1·09	11·6	12·7	,, ...	4·6	1·00	9·3	9·3
,, ...	4·6	1·09	12·9	15·6	,, ...	5·8	0·93	9·4	8·8
Persian print ...	6·0	1·00	8·3	6·7	Cretonne ...	7·2	1·58	14·0	11·4
,, ...	5·7	1·00	9·5	7·9	,, ...	7·2	1·25	18·0	11·0
Jacconette ...	5·8	0·98	10·4	8·2	Domett ...	6·4	1·79	7·1	7·0

interwoven at great spacings and fractional values would be found for the flimsy netting used to reinforce some packing papers, but the interwoven threads hardly seem a fabric unless the cover factors exceed 7. At about 9×8, there are a group of fabrics whose quality is "sheerness" and are intended to look light and open. About 11×10 is a favourite combination for fabrics intended to be opaque but soft and not too costly; 13×12 is a good, well-covered fabric for domestic use. Higher values in nearly square fabrics become increasingly stiff and hard, to the practical limit at 14-15 found in tent ducks. Higher values, up to 27, may be used in one direction, usually the warp, without excessive stiffness, but the weft must be more open, 10 or so, as in poplins and close canvases.

Of 58 plain constructions given by Hough, 34 have weft counts differing by less than 25 per cent. from the warp counts. The cover factors for these are plotted in Figure 6. The curve thereon represents the limit of setting for round threads with a specific volume of 1·1. Only one construction given exceeds this limit, that of the Tussore, and the cloth of the cutting provided by Hough is much more open than the particulars stated. Very strong yarns can, however, be beaten up to settings beyond this limit, their sections being flattened and dented to pack into a solid lamina.

The geometrical condition for the cramming of round threads represents no absolute limit on the setting of actual fabrics but it does indicate the stage at which distortion is necessary to produce a structure, with consequent difficulty in weaving and hardness of cloth. The condition for the closest

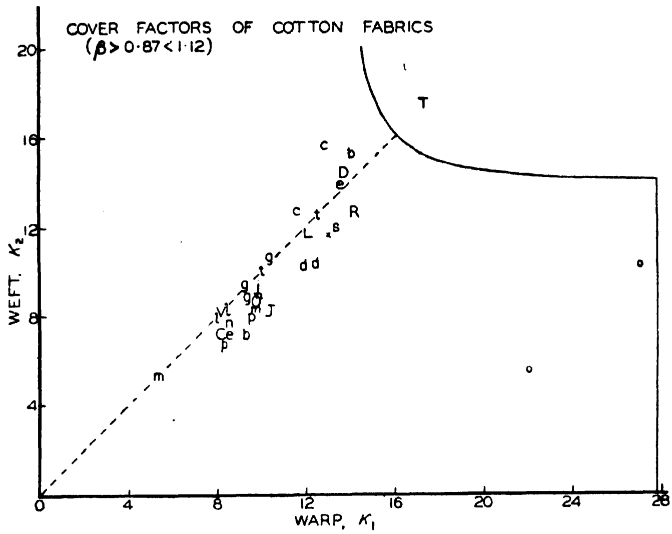


Fig. 6

Key.

b. Bafts.
c. Cambrics.
d. Madapolams.
e. Batistes.
g. Pongees.
j. Jaganaths.
l. Mulls.
m. Muslins.
n. Tanjibs.
o. Poplins.
p. Persian prints.
s. Shirtings.
t. T-cloths.
x. Mexicans.

B. Burnley printer.
C. Cheese cloth.
D. Tent duck.
J. Jacconette.
L. Lawn, longcloth
O. Organdie.
R. Bramante.
T. Tussore.
V. Voile.

weave, that $l/D = \theta$ for both directions, gives the relations :—

$$p_1/D = \sin\theta_1 = \sin l_1/D\ ;\ h_1/D = 1 - \cos\theta_1$$

$$\text{and } \cos\theta_1 + \cos\theta_2 = 1, \text{ or } \sqrt{1-(p_1/D)^2} + \sqrt{1-(p_2/D)^2} = 1 \quad \ldots (79)$$

These are easily evaluated by taking values of θ_1 and reading off from trigonometrical tables the corresponding values of the other quantities, according to these equations. From the smoothed curve, the closest picking may be calculated for any given spacing of ends and known counts.

Any one pair of values of p/D determines a geometrical construction of closest weave which applies on any scale and also to different count ratios ($\beta = \sqrt{N_1/N_2}$). To find the relation between cover factors, we have $D\sqrt{N_1} = 36\ (1+\beta)$ and

$$K_1 = \frac{27\cdot8}{1+\beta} \div \frac{p_1}{D} \qquad K_2 = \frac{27\cdot8\,\beta}{1+\beta} \div \frac{p_2}{D} \ldots \quad (80)$$

For equal threads, the closest constructions are then given by :

$$\sqrt{1-193/K_1^2} + \sqrt{1-193/K_2^2} = 1 \quad \ldots \quad \ldots (81)$$

which gives the curve plotted on Figure 6. This may be used for the majority of common fabrics, as small count differences may be ignored when considering cover factors.

Irrespective of interweaving, threads cannot be laid closer than their own diameter without overlapping, hence $p_1/D \nless (1+\beta)$ and $p_2/D \nless \beta/(1+\beta)$; neither can be less than 0·5 save for the thinner of two unequal threads. For equal threads, $p/D = 0\cdot5$ corresponds to a cover factor of 27·8, a value approached by warp-covered fabrics such as poplins and canvases ; the closest picking then gives a factor of 14.

For weaves other than plain, the possibility of over-riding of threads increases as the float length increases and it becomes increasingly easy for the threads to be bent sideways into contact when not separated by an intersecting thread. Over-riding is unsuited to analysis and only rough empirical rules could describe the limits of setting where this occurs. In the simpler twills of roughly square construction, over-riding is not evident.

The ideal geometry of such weaves gives the same limit of setting as for plains, for every thread is separated from its neighbours by intersection at some point of the repeat. Twills can certainly be woven more closely, partly because there is less resistance to enforcing the limit of setting but mainly because the threads can easily be forced sideways into contact between intersections. The effect of this on setting is the same as for a matt weave with the same float length, in which even the ideal geometry recognises two different spacings, one of parallel threads equal to the thread diameter or greater, the other at intersections conforming to the relations for a plain weave.

The limit of setting for parallel threads is the yarn diameter, whence $p'' = d = 36/\sqrt{N}$; for the intersections, $p' = 1000/K'\sqrt{N}$, where K' is the limit for a plain-cloth cover-factor found as above. Hence, using the value of p given on page T72, the cover-factor for the cloth as a whole,

$$K = \frac{f}{1/K' + 0{\cdot}036\,(f-1)} \qquad \dots \qquad \dots \qquad \dots (82)$$

For square fabrics, $K' = 16{\cdot}05$ and $K = \dfrac{30{\cdot}2\,f}{f + 0{\cdot}895}$, which may also be expressed as: $t = \dfrac{1{\cdot}09}{d} \cdot \dfrac{f}{f + 0{\cdot}9}$, where t is the number of threads per inch. This gives for the simpler twills and matts the following values of cover-factor: 2/1, 19; 2/2 or 3/1, 21; 3/3, 23·4. Twills of longer floats cannot be picked closely without over-riding.

There are attempts in the literature to generalise rules of cloth setting, with some approach to a geometrical basis in the use of the "intersection rule" and the measure of yarn size, $1/\sqrt{N}$. A considerable piece of work on the subject is summarised by S. Brierley in the "*Textile Manufacturer*," 1933, 59, p. 183, with references to other workers. His standard of setting is not intended to be the limit of practicability and is more open than that given by the above formula. He finds that the effect of floats is to increase the permissible setting in the ratio, f^m, where m varies with the type of weave, being 0·39 for twills of one move, 0·42 for satins, 0·45 for hopsacks. The above formula plotted logarithmically ($\log t/\log f$) gives roughly a straight line with the exponent, $m = 0{\cdot}39$, for simple twills, but the increase with float length is slower than that given by this empirical rule. It probably allows roughly for the over-riding of the threads, which increases with float length and, for the same f, from twill to satin to hopsack.

A valuable list of constructions, from which the values of cover factor for varied fabrics may be calculated, is given by Clark in "*Weave Room Calculations*" (2nd Edition, 1926).

Dimensional Changes in a Canvas.

The cloth was almost square, of moderately open weave, in the loom state. It had 32·4 ends per inch of 2/13·4s (very lightly sized) and 32·8 picks per inch of 2/12·6s. The crimps were, in the warp 8·7 per cent., in the weft 6·2 per cent.

After a standard washing treatment, shrinkages were observed of 2·6 per cent. warp-way, 4·8 per cent. weft-way, and the crimps were, in the warp 12·5 per cent., in the weft 10·3 per cent. The counts, re-determined, were 2/14s and 2/13·4s and the twists were :—two-fold, 12·2 and 11·7 turns per inch weft-way; singles, 9·9 and 10·0 turns per inch twist-way.

Strips, 18-in. × 2-in., were loaded in the wet state with weights recorded in Table V, allowed to stretch and dried by light ironing. Measurements were then made on the dimensions of the fabric and of the crimps of the threads, the results being recorded in Table V. The cloth changes are calculated on the basis of the shrunk fabric.

Table V.

Ref. No.	Direction of stretch.	Load, lb.	Extension in length, %	Contraction in width, %	Crimp %.	
					Warp	Weft
1	Shrunk	0	0	0	12·5	10·3
2	Warp	½	3·2	1·7	8·3	15·5
3	Weft	½	3·1	0·8	10·8	7·4
4	Warp	1	4·2	3·4	5·6	14·1
5	Weft	1	5·2	2·4	13·6	6·5
6	Warp	2½	9·6	7·9	2·8	20·7
7	Weft	2½	10·0	8·0	19·3	2·7
8	Warp	5	9·6	10·5	2·3	21·0
9	Weft	5	9·2	7·0	19·6	2·3
10	Warp	10	10·0	10·6	2·4	23·6
11	Weft	10	9·7	8·9	23·8	1·7

The calculations made on these data will be described with reference to the original cloth, Number 0. They may be done largely by slide-rule as this gives an accuracy beyond that of the measurements. The " threads per inch " are first converted into their reciprocals, the spacings p_1 and p_2, giving 30·9 and 30·5 mils. The spacings of the other cloths are given immediately by percentage additions or subtractions first of the initial shrinkages for cloth 1 and then of the values taken from Table V. The " yarn length l " intercepted between consecutive cross-threads is obtained by adding the " per cent. crimp," $l_1 = p_2(1+c_1)$. The first approximation to the sum of the diameters, $D' = \Sigma p\sqrt{2c}/(1+0{\cdot}2\,\Sigma c) = (12{\cdot}72+10{\cdot}88)/1{\cdot}0298 = 22{\cdot}90$. From the values of p_2/D' and c_1, the value of δ_1 if read off from Figure 3 ($\delta_1 = -{\cdot}001$, $\delta_2 = -{\cdot}002$) and the corrected value of D is obtained by a percentage addition, $D = D'\ (1+\Sigma\delta) = 22{\cdot}90\ (1 - {\cdot}003)$. The largest value of this correction, for cloth 2, is only $-0{\cdot}9$ per cent. and in no case would the correction of D lead to an appreciable change in δ. The values of h are now given directly from Equation (24*a*), by a small correction to the terms $p\sqrt{2c}$ already calculated.

The changes in the form of the threads, which accompany and complicate the crimp interchange, are shown by the values of l and D in Table VI. There is little systematic variation in yarn length, the thread along the extended direction being 1 per cent. longer than that along the contracted direction—mean l_1 33·2 and 32·9 respectively, l_2 32·8 and 32·5 mils. The sum of the diameters D, apart from some random error, shows appreciable variations of compression. The low value of cloth 0 seems to be a feature of the loom-state, which may be left to a later discussion. In the shrunk cloth, the observed counts give $34{\cdot}14\,\Sigma 1/\sqrt{N} = 12{\cdot}9 + 13{\cdot}2 = 26{\cdot}1$ mils, hence $v = (26{\cdot}7/26{\cdot}1)^2 = 1{\cdot}05$, a normal value for a fully-shrunk cloth of hard yarns, indicating well-rounded threads.

In the extended cloths, a reasonable simplifying assumption, based on the appearance of extracted threads, is that the extended threads are circular in section, with $d = 36/\sqrt{N}$, the distortion being all in the highly crimped threads of the contracted direction. The normal diameter of these threads, b,

calculated on this assumption, is given in Table VI, and the value $b/d=\sqrt{b/a}$ is the measure of the flattening of the threads (e). For warp and weft, the values of d are 13·6 and 13·9 mils respectively, ignoring the small variations of yarn length. In the loom-state fabric, the lightly-sized warp may be assumed to be the round thread and to have a diameter of 13·6 mils (a specific volume in cotton of 1·1). The value, $(b+h)$, of the more highly-crimped threads is then the theoretical thickness, apart from any extra compression imposed by the measuring device. The observed thickness, measured with a $\frac{3}{8}$-in. pedal under a pressure of 1 lb. per square inch, is given in the Table. It is, on the average, 3 per cent. lower than the calculated value, which does not include any allowance for the local irregularities that increase apparent thickness, so that there is some compression under the test conditions. The variations in crimp and diameter tend to cancel out in their effect on thickness, giving markedly high values, among the washed cloths, only in the shrunk and in the most strongly stretched fabrics. This is shown both by the calculated and the observed values, which are remarkably concordant for such a calculation and measurement.

Table VI.

Cloth No.	Spacings.		Yarn lengths.		D	Amplitudes.		Thickness, mils.			
	p_1	p_2	l_1	l_2		h_1	h_2	b	$b+h$	G	$G_{0\cdot5}$
0	30·9	30·5	33·1	32·8	22·8	12·3	10·5	13·6	25·9	26·1	—
1	29·4	29·7	33·4	32·4	26·7	14·1	12·6	12·8	26·9	26·3	27·3
2	28·9	30·6	33·2	33·4	27·0	11·9	15·1	*13·4*	28·5	25·6	27·4
3	30·3	29·5	32·6	32·5	24·3	13·1	11·2	10·4	23·6	24·8	26·2
4	28·4	31·0	32·7	32·4	24·4	10·0	14·4	*10·8*	25·2	25·0	25·7
5	30·9	29·0	32·9	32·9	25·1	14·4	10·8	11·3	25·6	24·8	26·5
6	27·1	32·5	33·5	32·7	24·0	7·5	16·5	*10·4*	26·9	24·7	26·2
7	32·3	27·3	32·6	33·2	23·5	16·1	7·3	9·6	25·7	25·2	26·2
8	26·3	32·5	33·3	31·8	22·9	6·8	16·1	*9·3*	25·5	25·1	25·9
9	32·1	27·6	33·0	32·8	23·2	16·5	6·7	9·3	25·8	25·1	26·2
10	26·3	32·7	33·4	32·5	24·0	7·0	17·0	*10·4*	27·4	25·6	27·0
11	32·2	27·1	33·5	32·8	23·5	17·7	5·8	9·6	27·4	26·5	27·7
Means, excluding 0			33·1	32·6	24·4				26·3	25·3	26·5

(The values of b pertain to the weft where they are printed in italics, otherwise to the warp, in all cases referring to the more highly crimped threads. Values are rounded off from a fourth place used in calculation, but of no significance.)

From curves of thickness plotted against pressure, it was estimated that a pressure of half a pound per sq. in. would yield the same average thickness as the calculated values (excluding cloth 0, in which the presence of size alters the compressibility). The values of thickness at this pressure are given in the column $G_{0\cdot5}$ and they agree closely with the theoretical estimates. In cloth 3, this estimate is given for the warp but actually the calculated value of $(b+h)$ for the weft is the greater, being 25·2 mils.

The correlated changes in crimp and cloth dimensions in warp and weft directions are compared in Figure 7 with the relation obtained from the geometrical theory, assuming the mean values of yarn length and diameter. This relation is easily and accurately calculated from Table I. Using four figures for calculations, $l_1/D=1{\cdot}353$, $l_2/D=1{\cdot}336$. Taking a value $l_1-p_2=0{\cdot}04D$, the value of h_1/D is, by interpolation, 0·313 ; hence $h_2/D=0{\cdot}687$ for $l_2/D=1{\cdot}336$. By interpolation, this gives $l_2-p_1=0{\cdot}247D$. From the values of l and $(l-p)$ so found, obvious calculation gives p, as p/D or in mils,

and $c=(l-p)/p$. The values in this case are: Warp:—crimp 3 per cent., $p_2/D=1{\cdot}313$, $p_2=32{\cdot}1$ mils; Weft:—crimp 22·5 per cent., $p_1/D=1{\cdot}090$, $p_1=26{\cdot}6$ mils. (With the model, the relation between p_1 and p_2 may be determined with the greatest ease and quite accurately enough.)

The assumption of invariant length and diameter gives quite a useful expression of the related changes in warp and weft directions. The next approximation depends on the determination of simple and general rules for

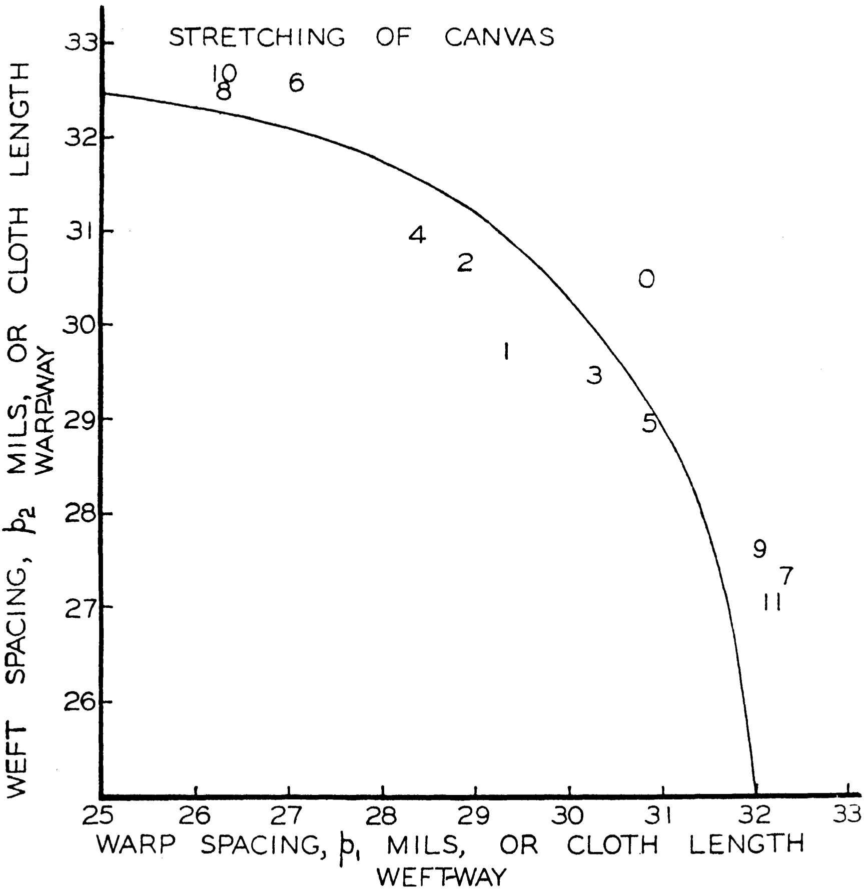


FIG. 7.

The curve gives the theoretical relation of length and width, neglecting change of yarn length and flattening.

the extension and compression of the threads under the known conditions by which the dimensional changes are produced. In this case, such rules might be framed as follows. "The yarn length varies by ±0·5 per cent. according to the direction of stretching of the cloth. The value of b/d is unity for the extended direction, 0·74 for the contracted." The establishment of such rules will, however, be left to studies specially directed to that purpose.

Analysis of Shrinkage.

Shrinkage may be regarded as a change in yarn spacing, p. From the formula, $p_1=l_2/(1+c_2)$, the observed shrinkage may be considered as the

resultant of the change in yarn length and the change in crimp. The crimp change is a combination of change in crimp distribution and in the general level of crimps dependent on the values of l/D. As a change in the values of l alone involves a change in crimp also, the several effects are not independent but they may be separated by adopting a convention sufficiently close to the facts for practical analysis.

The shrinkage may be imagined to occur in two stages, first the change in l and D due to the wetting and drying, during which the crimp balance or ratio remains constant, followed by a crimp redistribution to the final shrunk state. In the first stage, the crimps are affected by the changes in yarn lengths but to a small extent, any considerable effect being due to swelling of the yarns resulting in a change in D. The change in the factor, $1/(1+c)$, may be ascribed accurately enough to the swelling, that in l to the yarn length change.

For illustration, observations may be quoted on a mercerised poplinette, with 110·3 ends per inch of 36's count and 59·5 picks per inch of 33·5's count. After washing, shrinkages were observed of 2·98 per cent. in the warp and 1·61 per cent. in the weft direction. The crimps were 4·25 per cent. in the warp and 6·30 per cent. in the weft before shrinkage and 7·03 per cent. in the warp and 7·60 per cent. in the weft after the shrinkage.

The analysis begins with the determination of the structural features (p, l, h and D) by methods already sufficiently illustrated.

Table VII.

Structures Before and After Shrinkage.

Quantity.	Before.		After.	
	Warp	Weft	Warp	Weft
Counts	36·0	33·5	35·8	33·5
Spacing, p mils.	9·06	16·81	8·92	16·31
Crimp, %	4·25	6·30	7·03	7·60
Yarn length, l, mils.	17·53	9·64	17·46	9·60
Amplitude, h, mils.	4·82	3·08	6·00	3·28
$d=36/\sqrt{N}$	6·00	6·21	6·01	6·21

The sum of the diameters, $D=h_1+h_2$, increases from 7·90 to 9·28 mils, causing an increase in crimps which is responsible for most of the shrinkage. The mean ratio of flattening, $e=(h_1+h_2)/(d_1+d_2)$, increases from 0·63 to 0·74. The small changes in yarn length, $-0{\cdot}4$ per cent. in warp and in weft, cause direct proportional changes in cloth length but their subsidiary effect on crimp is negligible against the change of 17·5 per cent. in D. There is also a crimp redistribution towards more equal crimps which increases the warp shrinkage relatively to the weft.

To evaluate these effects separately, we adopt the convention stated above, that the shrinkage occurred in two stages—the change in values of l and D, maintaining the original crimp distribution, followed by a redistribution of crimp with the new values of l and D. The question then arises

how one should define a constant crimp balance when the yarns change in length and diameter. The general idea is certainly of significance, for a large redistribution of crimp from weft to warp commonly occurs in washing loom-state fabrics, apart from any swelling or shrinkage of the yarns. The uncertainty comes in defining the exact criterion, the feature which remains constant when a fabric changes its crimps to accommodate swelling without any redistribution from one direction to the other. The obvious criterion is the ratio, c_2/c_1, but one might also suggest the values of h/D, the difference $(c_1 - c_2)$ between the two crimps, and other reasonable measures of the form of the structure. If the crimps adjusted themselves to swelling so that the shrinkages accompanying equal changes of yarn length were equal in warp and weft directions, the ratio $(1+c_2)/(1+c_1)$ would remain constant. For the analysis of shrinkages, this is a suitable convention, as one figure expresses the shrinkage due to swelling, any differences between warp and weft being allocated to yarn length changes or crimp redistribution.

In the first stage, then, the values of l and D change to their final values, making $l_1/D = 1{\cdot}882$, $l_2/D = 1{\cdot}035$, while the crimps are forced up by the swelling so that $(1+c_2)/(1+c_1)$ remains $1{\cdot}0196$. To determine the structure, it is necessary to determine the relation between c_1 and c_2 and find the point where the necessary condition holds. This condition may, however, also be expressed as $\dfrac{p_2}{p_1} = \dfrac{l_1}{l_2} \cdot \dfrac{1+c_2}{1+c_1} = 1{\cdot}852$ and the point satisfying it is shown on the relation, $p_1 - p_2$, or of the cloth dimensions, in Fig. 8. It is defined by the values $c_1 = 6{\cdot}62$ per cent., $c_2 = 8{\cdot}70$ per cent.; $p_1 = 8{\cdot}84$ mils, $p_2 = 16{\cdot}38$ mils.

The first stage may also be divided into two parts, the yarn length change being isolated by imagining the crimps maintained constant by the necessary adjustment of the diameters. The total shrinkage is then analysed into three parts, (1) a yarn shrinkage of 0·4 per cent., causing a proportionate cloth shrinkage, in both directions, with unchanged crimps; (2) swelling of diameters producing an increase in both crimps such as to cause equal shrinkages of 2·15 per cent.; (3) a redistribution of the crimps to their final values, adding 0·83 per cent. to the warp shrinkage and diminishing the weft shrinkage by 0·94 per cent.

Now that the method of analysis has been explained, a second example may be given to show the procedure of separating the three effects most expeditiously. The material was a plain cloth in the finished state with 92·8 ends of 21·4's and 42·1 picks of 12·4's per inch. Taking reciprocals gives $p_1 = 10{\cdot}78$, $p_2 = 23{\cdot}75$. The observed shrinkages were 8·5 per cent. and 2·4 per cent., giving for the shrunk state $p_1 = 10{\cdot}52$, $p_2 = 21{\cdot}73$. The crimps were 5·3 per cent. and 5·3 per cent. before shrinking, giving $l_1 = 25{\cdot}01$, $l_2 = 11{\cdot}35$; after shrinking, the crimps were 14·8 per cent. and 6·9 per cent., giving $l_1 = 24{\cdot}95$, $l_2 = 11{\cdot}24$. Hence, the yarn shrinkages were 0·24 per cent. in the warp, 0·92 per cent. in the weft.

The value of D in the final state is now determined by Equation (28a), being 15·02 mils. The structure has therefore to be determined in which $l_1/D = 1{\cdot}66$, $l_2/D = 0{\cdot}75$ and $(1+c_2)/(1+c_1) = 1$, i.e. $c_2 = c_1$. By interpolation in Table I, this is found when the crimps are 11·56 per cent. A change of crimp from 5·3 per cent. to 11·56 per cent. represents a shrinkage of 5·61 per cent. This may be added to the yarn shrinkages to find the shrinkages without crimp redistribution, the effect of which is found by difference from the observed shrinkages.

The shrinkages of this cloth are thus analysed as follows :—

Cause of shrinkage.	% Shrinkage, warp-way.	% Shrinkage, weft-way.
Yarn shrinkage	0·24	0·92
Swelling	5·61	5·61
Crimp redistribution	2·65	−4·13
Total observed	8·5	2·4

Strictly, percentage shrinkages in successive stages are not additive, the total shrinkage s being given by $(1-s)=(1-s_1)(1-s_2)(1-s_3)$ where s_1, s_2, s_3, are the successive shrinkages, but the above calculation gives the shrinkages based on the original lengths without appreciable error, the yarn shrinkages being small.

Though this calculation is sufficient to separate the effects, further features may usefully be evaluated in the study of the physical causes of shrinkage. If tension in weaving or finishing appears to be the predominant cause of the instability of dimensions, the values of θ may readily be found from Equation (15). This cause is not indicated here as the warp yarn shrinkage is so small. This fact, combined with the large effect of swelling indicates calendering as the main cause. A large excess of crimp in the warp is to be expected after any condition in which the elastic forces can control the structure, as the intercepts of warp yarn are longer and finer than those of the weft. The crowns of the warp intercepts or floats are therefore prominent and will be pressed down in calendering, by flattening of the yarn sections, by redistributing crimp from warp to weft and by some stretching of the weft. The original finished cloth has a structure in which warp and weft are almost equally on the surface and the threads are much flattened, so that all the features indicate calendering as the predominant cause of the unstable structure of the finished cloth.

These effects are studied by determining the values of D, in comparison with those of d calculated from the counts, and of h, which determine the over-all cloth thickness due to either set of threads, warp and weft. In the original cloth, the value of D is 10·98 mils, while the diameters from the counts are 7·78 and 10·22 mils, giving the mean value of the flattening ratio, $e=b/d=0{\cdot}61$, which is typical of a well-calendered cloth. The shrinkage of 5·6 per cent. is due to the increase of this ratio to 0·83, a value normal for a shrunk cloth.

The amplitudes (original) are 7·64 and 3·34 mils. If b/d were the same for warp and weft, the thickness between crowns of warp would be $(b+h)=4{\cdot}74+7{\cdot}64=12{\cdot}38$ mils ; weft 9·58 mils. The protruding warp would certainly get more flattening in calendering, and the figures are quite consistent with the supposition that a structure similar to the shrunk cloth has been calendered till the warp and weft crowns were level, the more compressed warp recovering more after treatment. The amplitudes of the shrunk cloth are 11·49 and 3·68 mils ; the values of $b=d.e$ are 6·48 and 8·54 mils, and the thicknesses, $b+h$, 17·97 and 12·22.

If the cloth in this shrunk state were again subjected to the calender finish for a shirting, it would probably return to a structure and dimensions similar to those of the original cloth as the warp projects nearly 3 mils on either side beyond the weft and would take the brunt of the calendering.

The excessive shrinking observed is therefore of quite a different category from that due to excessive warp tension or to high yarn twists.

A further example may be given to illustrate the application to a twill cloth. A 2/2 twill shirting showed a shrinkage in the warp of 8·0 per cent., in the weft 2·4 per cent. The finished cloth had 72·6 ends of 13·5s, 54·4 picks of 12·2s, with crimps of 5·6 per cent. and 5·9 per cent. which changed after

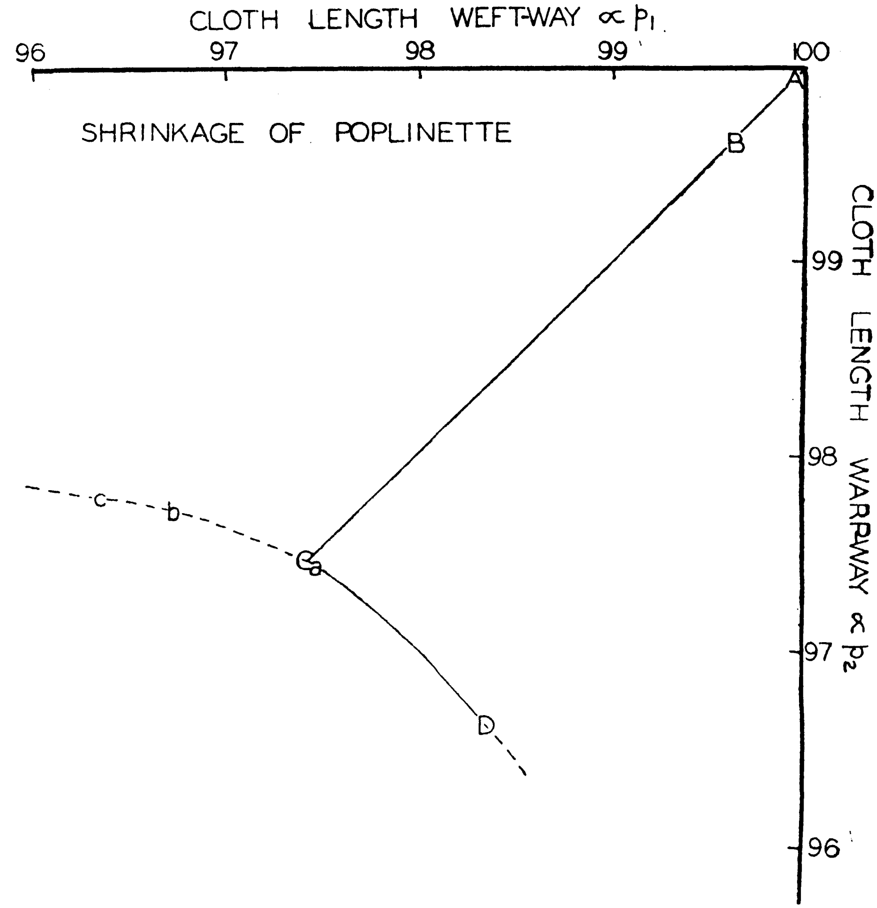


Fig. 8.

Full line :— Imaginary sequence of length changes, due to : A-B, yarn shrinkage ; B-C, diameter swelling ; C-D, crimp interchange.

Broken line :— Cloth dimensions, with final yarn lengths and diameters, showing points corresponding with different criteria of constant crimp balance : a, difference of crimps ; b, ratio of crimps ; c, value of h/D ; C, ratio of spacings, respectively constant.

shrinking to 13·4 per cent. and 7·5 per cent. The spacings and yarn lengths are calculated as before, irrespective of the weave, giving $l_1 = 19{\cdot}41$, $l_2 = 14{\cdot}59$ mils before shrinking and $l_1 = 19{\cdot}18$, $l_2 = 14{\cdot}45$ mils after shrinking, showing yarn shrinkages of 1·20 per cent. and 0·93 per cent., and therefore no evidence of warp stretch.

To calculate the amplitudes and D, the idealised structure is assumed in which the yarn in a float passes straight from the top of one cross-thread

to the next, and at an intersection has the form of a thread of a plain weave, with twice the observed crimp. Equation (28a) is therefore applied, with the actual values of p and doubled values of c. In the original cloth, D is 14·58 mils and $e = D/(d_1+d_2) = 0{\cdot}725$. This shows less compression than in the plain shirting, a difference which may be partly real, as the yarn may recover more in the more open weave, but would also be partly explained by a curvature of the floats.

In calculating D for the shrunk cloth, it is found that the first estimate $D' = 18{\cdot}20$ mils, making $p_2/D' = 0{\cdot}93$. With $c_1 = 26{\cdot}8$ per cent., the point representing the warp lies very close to the limit of jamming, with $\delta_1 = -0{\cdot}011$. The point for the weft, $p_1/D = 0{\cdot}739$, $c = 15{\cdot}0$ per cent., lies actually over this limit, though so little that an estimate of $\delta_2 = -0{\cdot}022$ may be made. These comparatively large corrections make a second approximation to D', p/D and δ desirable, though the effects even in this case are small. The points still lie just to one side and the other of the limiting structures.

The value of D is found to be 17·73 mils, making $e = 0{\cdot}873$, $h_1 = 11{\cdot}27$, $h_2 = 6{\cdot}46$, $b_1 = 8{\cdot}60$, $b_2 = 9{\cdot}11$, and the thickness due to warp and weft respectively $(b_1+h_1) = 19{\cdot}87$, $(b_2+h_2) = 15{\cdot}57$. Again, the tendency to shrinkage of this shirting may be ascribed to the fact that the elastic balance of crimps, allowed freedom to act in the washing and drying, puts a high crimp into the warp whereas the calendering of the finished shirting has flattened the protruding warp.

It is not, however, to be regarded as an accident that both warp and weft approximate closely to the jammed structure. As the yarns swell, the crimps increase and the dimensions shrink to accommodate the diameters and to balance the elastic forces. Suppose, however, as appears to be the case, that this proceeds till the weft becomes jammed between the closely-spaced ends of warp. The swelling can then be more easily accommodated by the further crimping of the warp, until this also jams. The balance of crimps in such a case is limited and largely determined by the geometry of the structure.

No other balance is indeed possible without further compression of the threads, as any straightening of one jams the other more tightly. It is not therefore possible to divide the shrinkage as in the previous examples, for during the process of swelling, the weft jams and further swelling can only occur by an increase in warp crimp. The stages of the imaginary process may be reversed without transgressing geometrical possibility and with only negligible effect on the parts allotted to the separate causes.

To determine the structural changes in a redistribution of crimp in a twill, the relations of the plain weave are applied to the quantities pertaining to intersections. If the total yarn length remains constant and the thread paths are not distorted, $l_1 = p_2\,(1+c_1)$ remains constant, but not the yarn length, l', in an intersection to which the formulae are applied, $l_1' = p_2(1+2c_1)$, for yarn can be taken up or paid out to the floats.

In adapting the criterion for swelling without change of crimp distribution, a reasonable convention is again all that can be decided at present. Equal shrinkage, irrespective of weave, would not be reasonable, nor indeed possible in many weaves where one set of threads has long floats, the other short. The criterion may be adapted by assuming the shrinkage per intersection, with no yarn length change, to be the same for warp and weft. It is then the same for this 2/2 twill as for a plain.

The first imaginary stage of the shrinkage process will therefore be a crimp interchange till $(1+c_2)/(1+c_1)$ has the final value 0·948, while $l_1/D=1{\cdot}331$, $l_2/D=1{\cdot}001$. The plain-weave tables are read for values $p=1{\cdot}331/(1+c)$, $l'=p\ (1+2c)$ and $c'=2c$, and the required conditions are satisfied when $p_2/D=1{\cdot}227$, $p_1/D=0{\cdot}973$, $c_1=8{\cdot}55$ per cent., $c_2=2{\cdot}90$ per cent., the shrinkage being 2·72 per cent. warp-way, and −2·92 per cent. weft-way. The swelling then changes the crimps to the final values, 13·4 per cent. and 7·5 per cent., a change which by itself represents a shrinkage of 4·27 per cent., and this is followed by the yarn shrinkages as given, 1·2 per cent. and 0·93 per cent.

These parts do not add up precisely to the total shrinkage, as the basis of percentage for the parts changes at each stage. To avoid variations due to the order of the imaginary stages, the yarn shrinkages and those due to swelling are left as given by this calculation, the slight adjustment being made at the expense of the crimp redistribution. The analysis is then :—

Cause of shrinkage.	% Shrinkage, warp-way.	% Shrinkage, weft-way.
Yarn shrinkage	1·20	0·93
Swelling	4·27	4·27
Crimp redistribution	2·53	− 2·80
Total observed	8·0	2·4

The behaviour of this twill is very similar to that of the plain shirting, and the crimps, both before and after, are alike. By the difference in weave, this similarity is attained with a closer weft, which would make a plain cloth too hard. The cover factors of the twill are 19·8 and 15·6, those of the plain 20·0 and 12·0.

Balance of Crimp in Shrunk Plain Cloths.

In a fabric free from tension or pressure, the crimps adjust themselves so that the elastic forces are in equilibrium—the flexural forces in an open cloth, with internally balanced tensions added in crammed structures. The curvature of the crimped threads is not, however, all elastic ; if released from all external restraint, they would retain most of the curvature as a " set." The setting of the crimp has in general more influence on the crimp balance than have the active elastic forces, and the set crimps depend on the history of the fabric, that is, on tensions and pressures in relation to time, moisture and temperature.

Almost any balance of crimps geometrically possible may be imposed on any cloth. That balance of crimps which corresponds to the equilibrium of elastic threads should, however, be favoured by cloth subjected to changes of swelling while free from restraint, so that shrunk fabrics should show a tendency to approximate to this balance. According to this analysis, the balance should be given by Equation (73), which may be expressed in the form

$$\log.\ c_1/c_2=4\ \log.\ t_1/t_2+2\ \log.\ m_2/m_1.$$

The last term is a constant for a group of fabrics with a constant ratio of warp to weft counts if the warp and weft are of similar type as regards flexural rigidity.

To establish general relations for the crimp balance of shrunk fabrics will demand a statistical survey of some magnitude, with a fairly close study of the many features which may vary the balance. The data to be presented

are a mere illustration on the first available material, obtained from a miscellaneous lot of fabrics which were desized and tested for count, and incidentally crimp, for other purposes not calling for the high precision of a test of geometrical theory.

There were 58 plain cloths and the ratio of N_1/N_2 was distributed as follows, in intervals of 0·1, e.g. from 0·550 to 0·649, which is designated by the interval mean 0·6.

Interval mean ...	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	above 1·5
Number ...	3	3	12	15	5	1	2	4	13

Nearly half the values fall in the two intervals from 0·75 to 0·95, with a mean 0·854. Fig. 9 is a plot of the values obtained from these 27 fabrics. Though subject to some variation due to the known count ratio and to unknown differences in intrinsic stiffness of threads, this plot should give some indication of the crimp balance for similar threads as the spacings vary.

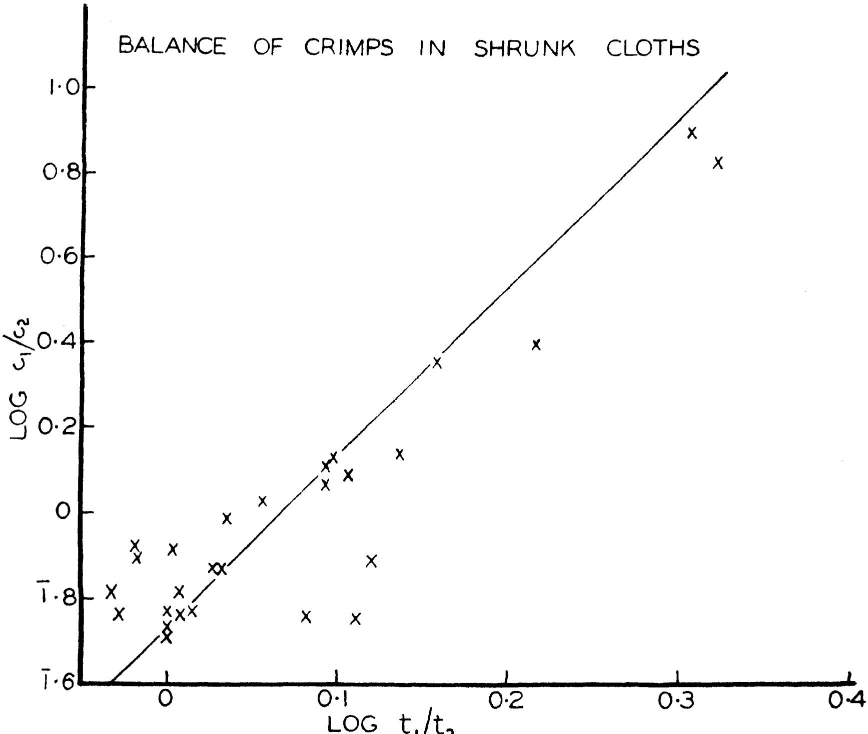


Fig. 9.

The straight line represents the theoretical relation for coherent threads ($m \propto 1/N^2$) having the mean count ratio 0·854. It is not a close approximation to the line of "least squares" but it does represent quite a reasonable relation for the elastic balance. If we suppose this relation attained in the free wetting and drying, the final ironing flattens the more prominent crowns and this would account for much of the deviation observed.

Crimp Balance in the Loom State.

A poplinette warp was woven with a series of nine settings of the take-up to vary the picks per inch, the weft being the same for all. The unsized warp was of 50's count, and the mean count of the sized warp was 43·8. The mean weft count was 51·6's with 21 turns per inch. Observations were made on the structure of samples of each cloth and loom particulars are available for comparison. The total number of ends was 5,280 and the width of each sample was measured, giving the mean number of ends per inch. Allowing for the selvedge, the total number of ends is taken as 5,268, the mean of the values of the product of measured widths and ends per inch. In Table VIII below, the data are presented in a form suited to comparison. The cloth width per end is the measured width divided by 5,268, in mils. This is directly comparable with the end spacing, the reciprocal in mils of the measured ends per inch, and, when the percentage of weft crimp is added, it gives a measure of the pick length, in mils per end, which should be constant save for any yarn extension, variation of picking tension or errors of crimp measurement.

The take-up was varied to give nominal picks per inch of 40, 50 . . . 120 picks per inch (cloths A to I in Table VIII), allowing for an increase of 4 picks per inch, i.e. take-ups on the sand-roller of 36, 46 . . . 116 picks per inch, which are expressed as their reciprocals in mils, to compare with the pick spacing.

From the cloth structure as measured on the samples, the effective sum of diameters, D, is calculated in the usual way, and $\bar{e} = (d_1+d_2)/D$ is calculated, taking $d_1 = 36/\sqrt{N_1}$, where N_1 is the count of the unsized warp ; $d_1 = 5{\cdot}09$, $d_2 = 5{\cdot}01$.

Table VIII.

Cloth	Width per end, mils.	Take-up per pick.	Pick length per end.	Spacing of		Crimps.		D	$\bar{e}$
				Warp p_1	Weft p_2	Warp c_1	Weft c_2		
A	7·12	27·78	7·31	7·08	27·70	5·1	2·7	10·33	1·02
B	7·12	21·74	7·31	7·13	21·60	6·5	2·7	9·27	0·92
C	7·11	17·86	7·37	7·12	17·79	9·7	3·7	9·54	0·94
D	7·10	15·15	7·42	7·10	15·08	11·6	4·5	9·10	0·90
E	7·09	13·16	7·42	7·09	12·97	15·3	4·7	9·00	0·89
F	7·07	11·63	7·30	7·07	11·43	16·0	3·2	7·98	0·79
G	7·05	10·42	7·30	7·05	10·19	19·1	3·5	7·86	0·78
H	7·06	9·43	7·31	7·07	9·43	24·2	3·5	8·02	0·79
I	7·06	8·62	7·31	7·07	9·22	25·3	3·6	8·04	0·80

The width of the warp in the reed was 37·7 inches, and about the same at the temples, giving a width per end (on 5,268 ends) of 7·16 mils, to which must be added the bow and the extension of the weft to give the pick length per end. This quantity, reckoned from the cloth width, shows no certain evidence of extension. The values obtained from measurements of ends per inch agree closely except for cloth A, where it is 7·27 mils. There may therefore be a small extension in the most open cloth, increasing by 1·5 per cent. up to the normal cloth E, but the close fabrics again show little extension.

As the unextended pick length is determined before beating-up and the cloth width is maintained for some time after weaving, the weft crimp is determined geometrically, save for slight additions due to weft extension and to width shrinkage. The shrinkage is not allowed for some time after weaving,

by which time the crimps are well set, so that it is small,—0·5 per cent. for A, increasing up to 1·4 per cent. for I. Thus the weft crimps could be determined closely enough by assuming a pick length 2 per cent. greater than the reed width per end and a cloth contraction of 1½ per cent., giving a crimp of 3½ per cent. Very open fabrics might contract less and there might be some variation of weft tension (bow) or extension, but there is little change of weft crimp with structure and the simple calculation should be a reasonable approximation for a wide variety of fabrics, woven of similar yarns on similar looms.

Under these conditions, the effect of the elastic balance is inappreciable—it would produce the greatest ratio c_1/c_2 in cloth A, where the ratio is actually smallest. The warp crimp is simply that necessary to weave round the already determinate length of weft. As it increases, the warp tension imposes more pressure on the weft but can affect its length little. From the values of c, it appears that the most lightly picked cloth has round threads barely touching; the next four, up to the normal fabric E, show a very mild degree of flattening; above 80 picks per inch, the threads are distinctly flattened, to an equal degree up to the closest fabric. It was impracticable to weave closer than cloth I, with 108 picks per inch, but this fabric does not approach the limit of cramming on Fig. 2. Probably the weft is driven up to jam the warp at the beat-up—otherwise closer weaves should be practicable—but the cloth opens up somewhat after weaving. The weft spacings show a small and increasing contraction from the length on the sand-roller, up to 98 picks per inch (G), no change from the take-up movement at 106 picks and a marked extension in the closest weave. It is only with very strong folded yarns, or flax and the like, that crammed structures are observed in the loom state.

The degree of openness or "play" relative to the limit of close weaving may be expressed by the value of $(\frac{l}{D} - \theta)$, the straight portion of the thread, which is zero when the thread is jammed. If θ is to be used frequently, its values should be tabulated against appropriate quantities, but it may readily be calculated from Equation (15). For cloth I,

$$t_1 = \frac{9{\cdot}22 - \sqrt{85{\cdot}01 + 3{\cdot}28 - 64{\cdot}64}}{8{\cdot}04 + 1{\cdot}81} = 0{\cdot}443$$

$$\theta_1/2. = 23{\cdot}9^\circ = 0{\cdot}417 \text{ radians, } \theta_1 = 0{\cdot}834$$

$$l_1/D = 1{\cdot}438 \text{ and } \frac{l_1}{D} - \theta_1 = 0{\cdot}604.$$

The pick spacing which would jam the warp may be calculated for the conditions at the beat-up. The given features are that $p_1 = 7{\cdot}16$ mils, $l_2 = 7{\cdot}31$ mils, $D = 8{\cdot}04$ mils and $\frac{l_1}{D} - \theta_1 = 0$. Hence $p_1/D = 0{\cdot}892$, $c_2 = 2{\cdot}09$ per cent., and $h_2/D = 0{\cdot}174$, $h_1/D = 0{\cdot}826$. From Table II, jamming occurs at this amplitude when $p_2/D = 0{\cdot}984$, i.e. $p_2 = 7{\cdot}91$ mils and there are 126 picks per inch at the beating up of the fell. There is an immediate expansion as the reed pressure is released and another when the cloth is released from the loom. A total expansion of 14 per cent. would produce the pick spacing of cloth I, with 108 picks per inch.

From the values of θ_1 and θ_2, an estimate may be made of the tension put on the weft by the warp tension, say just after the beat-up of the next

pick, using the equation, $T_1 \sin \theta_1 = T_2 \sin \theta_2$. The extension of geometry to statics demands, however, still more caution and reservations, checked by experimental data.

Though the structures of the loom-state cloths are practically determined by the almost constant weft crimp and yarn diameters, very different crimp changes may be expected when the fabrics are processed. In wetting and drying, an approach towards an elastic balance must be expected, which will increase crimp preferentially in the warp of the more open cloths, while in G and H the crimp ratio should change the other way and I will probably jam. Calendering will force crimp from warp to weft in all the cloths, jamming the closer ones. A reasonable estimate of the calendered structures could be made by a simple application of geometry, assuming that e falls to say 0·7 and that the warp crowns are depressed to say 1 mil only above those of the weft.

Extension and Tensile Test of Flax Canvas.

Structural analysis of this tenting canvas gave threads per inch $39{\cdot}4 \times 39{\cdot}4$, counts on cotton system 4·8's and 4·4's and crimps 26·4 per cent. and 1·5 per cent. A cutting was held for 24 hours at 20 per cent. extension, released, and after another four days showed a residual extension of 14 per cent. Another analysis then gave the figures $41{\cdot}2 \times 35{\cdot}6$ threads per inch of 4·7's and 4·3's, with crimps 13·3 per cent. and 5·3 per cent.

From the threads per inch, the warp-way extension is 10·7 per cent. and the weft-way contraction 4·4 per cent. The change in crimps would account, with constant yarn lengths, for an extension of 11·6 per cent. and a contraction of 3·6 per cent.; but yarn extensions would increase the former, decrease the latter. Thus the various data are not in precise conformity.

In previous examples, precise calculations have been made on data accepted without question of exactitude. But cloth analysis cannot attain such precision, and destructive analyses must be made on different portions of a variable fabric. The problem must often arise of applying calculations to structural analyses subject to variation and error. A choice must then be made of the evidence, using the data so that the conclusions will be affected as little as possible.

To determine D, the actual analyses must be used and these give values 21·8 mils before, and 21·5 mils after extension. The values of the diameters $(d_1 + d_2)$, assuming $v = 1{\cdot}1$ and counts as measured, are $(16{\cdot}4 + 17{\cdot}2) = 33{\cdot}6$ mils before, and $(16{\cdot}6 + 17{\cdot}4) = 34{\cdot}0$ mils after, making e 0·65 before, and 0·63 after extension. This small change is in the expected direction, but its reality is hardly established by the accuracy of the data. The flax yarns are hard and already subjected to high pressure in weaving this close fabric.

The best measure of extension is given by the change in length of one and the same portion of fabric, so the figure of 14 per cent. is accepted, allowing for the discrepancies in the other data by variations of threads per inch and inaccuracy of crimp measurements. Single thread tests on yarn taken from the cloth before and after extension give evidence that the yarn extensions are small, as is to be expected in the circumstances. Count figures are not significant in this connection. The results of the tensile tests are :—

	Before.		After.	
	Warp	Weft	Warp	Weft
Breaking load, lb.	7·36	8·56	6·86	8·20
Extension, %	6·2	4·2	5·1	4·2

A calculation will be made of the change in the original structure, as measured, when extended 14 per cent., assuming that e falls to the value 0·63, and that the warp yarn extends 1 per cent., the weft yarn remaining constant in length. This example is given for its general interest as such calculations will become possible when, through generalisations of data obtained from analysed structures, changes in l and e become predictable.

The new counts are then 4·85's and 4·40's, and $D = 0{\cdot}63 \times 36\ \Sigma\, 1/\sqrt{N} = 21{\cdot}2$ mils. After extension of 14 per cent., p_2 becomes 28·9 mils, making p_2/D 1·36. The yarn lengths, from 32·1 and 25·8, become 32·4 and 25·8 mils, hence $l_1/D = 1{\cdot}52$, $l_2/D = 1{\cdot}21$. From Table I, $h_1/D = 0{\cdot}593$, hence $h_2/D = 0{\cdot}407$, and from the same Table, $c_2 = 7$ per cent., making $p_1 = 24{\cdot}1$ mils. The extended structure would thus have 41·5 ends of 4·85's count, 34·6 picks of 4·4's count, with crimps 12 per cent. and 7 per cent. This structure differs from that observed no more than may be expected from quite slight and probable variations and errors in counts, thread spacing, crimps and actual extension.

Warp-way strips of the extended material were tested, 7-in. × 2-in. between the grips, on a Goodbrand Cloth Testing Machine and gave a breaking load of 474 lb. (5·75 lb. per thread) and extension of 16·8 per cent. Assuming that the extension of the warp yarn at break is equal to that found in the single thread test (5·1 per cent.), that of the weft being zero, we have for the structure at break, $p_2 = 32{\cdot}81$ mils, $l_1 = 33{\cdot}45$ mils, $l_2 = 25{\cdot}56$ mils, hence $c_1 = 1{\cdot}95$ per cent. To maintain this crimp against the warp tension, the weft must be jammed, and this condition is sufficient to define the structure, which must be determined by successive trials of values of D. A few trials fix this at 20·4 mils, a very reasonable value which is checked as follows: $p_2/D = 1{\cdot}608$, from Table I, $h_1/D = 0{\cdot}313$, hence $h_2/D = 0{\cdot}687$. From Table II, $l_2/D = 1{\cdot}252$, hence $D = 25{\cdot}56/1{\cdot}252 = 20{\cdot}4$. From Table II again, $c_2 = 32{\cdot}0$ per cent., $p_1/D = 0{\cdot}9484$, $p_1 = 19{\cdot}35$ mils.

The contraction in width, according to this calculation, is 20·2 per cent. Both the extension and contraction may be divided as before into the parts due to changes in yarn length, compression and crimp distribution, but in this case the effect of compression is very small. Allowing for the change in counts, the final value of e is 0·61. Even this one example serves to determine the likely changes in l and D sufficiently to predict the tensile behaviour of flax canvases of different structure.

In the tensile test, the width is maintained constant at the ends of the strip, by the grips, so that the paths of the yarns are distorted from an orthogonal net and the spacings, crimps, etc., vary over the strip. The calculations should be applied to changes at the centre where, by symmetry, the orthogonal condition persists. Observations have been taken on the differential extension along the strip and the difference between the central and average values was found very small. The effect of the end distortion is only of the order of errors of observation, particularly of the extension at "rupture," a point difficult to determine precisely.

More rigorous analysis of the strains of a fabric under stress is, however, desirable for several reasons. The end grips of the tensile test are a constraint on the contraction, which would probably be greater in cloth perfectly free to contract. Scientific "fabric engineering" awaits the development of a theory of stress and strain, capable of correlating the behaviour under

different boundary conditions—a loaded strip, a balloon envelope, a water bag or filter cloth, a parachute, guyed tent, etc. This is being approached by several paths, such as more detailed observations and analysis of the tensile test, development of other tests of more simple and definite theoretical character, structural changes of fabric in use and the development of a differential geometry of the yarn network.

SUMMARY.

If measurements of cloth structure are presented as a number of absolute length measurements, such as for example, thread spacings and diameters, the geometrical form of the structure and the extent of its similarity to other structures, is not immediately evident. If, however, one such measurement be chosen as a basic length merely to show the scale of the structure, and if all the other measurements are then expressed as ratios relative to it or to each other, then similarities or differences of geometrical form stand out clearly and geometrical analysis has a general validity, which is independent of the scale. Physical studies may then proceed from geometry by the use of physical constants of the material and laws describing the effect of scale or absolute dimensions. To link up the usual weight units of textiles with geometrical analysis, quantities based on the inverse square root of the yarn counts are suggested.

The ideal geometry of the plain weave is given, first by rigorous formulae in terms of the angles of bending and the lengths of the interweaving threads. (Equations 9-16.) Explicit relations between the observed features, threads per inch and crimps, are obtained by computation and given by Tables I and II. These may also be determined by a mechanical model, Fig. 3. The sum of the thread diameters is adopted as the scale of the structure and is determined from the observed features by an approximate formula (Equation 28a), corrected by a diagram (Fig. 4). Comparison of this sum with the counts gives a measure of the flattening of the threads, assuming a specific volume of 1·1. The relation between thread spacings, crimps and counts is also given as a simple, algebraic function, in an approximation of lower precision but equal to that of actual measurements (Equation 44).

It is shown that the flattening of the threads and their rigid resistance do not seriously disturb the application of geometry to cloth analysis. Changes in yarn length and flattening may be evaluated from analysis of known structures, or, if predictable, they may be used in conjunction with the geometrical relations in predicting cloth behaviour.

The idealised geometry of simple twill and matt weaves is given, with the reservation that the departure of actual from ideal forms may often be too great to allow the analysis any useful application. The relations can be reduced to forms given by the tabulation of the functions for the plain weave (Equations 48-50).

Some of the more important applications of geometrical analysis are described, by illustrations with data from actual fabrics. The limiting structures geometrically possible (without distortion) are defined by the rigorous geometry (Equations 17 and 18). Other special structures—square or warp-closed—are also determinable rigorously (p.T61 *et seq*). Cloth settings in commercial fabrics are discussed in relation to the analytical conclusions (p.T77 *et seq*).

The main applications are of two kinds—the determination of the lengths and diameters of the threads in known (tested) fabrics or, conversely, the prediction of structural changes when the lengths and diameters are known. The latter is usually a problem in crimp interchange, consequent on some known change in dimensions or other condition. According to the known condition, the problem takes various forms and the various methods of attack are discussed (p.T64 *et seq*). A preliminary reference is made to statics, the balancing of forces in the threads, either of tension of bending (p.T67), but an effective discussion of statics must await further development of the mathematical analysis.

Dimensional changes observed in experiments on fabrics are analysed into three components due to yarn length change, swelling of thread section or flattening thereof, and crimp redistribution. A canvas was stretched by various amounts warp and weft-way and the relations between length and breadth observed are compared with theory, also the changes in thickness (p.T80-83). The shrinkage of a poplinette is analysed into its three components, shown graphically as an imaginary sequence of the actually concurrent changes in Fig. 8. This analysis is given in a short form for another cloth, and the cause of shrinkage is traced to the difference between the crimp balances due to calendering and to elastic forces respectively. A similar discussion illustrates the geometrical analysis of a 2/2 twill and demonstrates that this cloth must have become jammed in both directions in the shrinkage test (p.T83-89). The balance of crimps in a set of shrunk cloths is analysed and shown to be reasonably accordant with the theory of elastic threads (p.T89-90). From data on a set of loom-state poplinettes of varied picks per inch, it appears that the crimps are determined mainly by the available length of weft in a pick. The last example is an analysis of the stretching of a flax canvas, in which the data show discrepancies due to error and variation, also of a tensile test thereon, from which it appears that a good prediction of the tensile behaviour follows from the theory, assuming the yarn to extend to the same amount as in a single-thread test.

Received 2/3/37

6.—THE APPLICATION OF DIFFERENTIAL GEOMETRY TO THE STUDY OF THE DEFORMATION OF CLOTH UNDER STRESS

By J. R. Womersley, B.Sc., D.I.C.
(British Cotton Industry Research Association)

1. INTRODUCTION AND SUMMARY

The study of the stress-strain relationships of cloth provides a unique opportunity for the application of the methods of differential geometry to a practical problem. The warp and weft threads, which are perpendicular straight lines in the ideal form of the cloth, become curved under stress, and form a natural system of curvilinear co-ordinates for the description of its deformed state. In the differential geometry of surfaces these " parametric " curves are usually chosen arbitrarily, or so as to give simple functional relations for the description of the properties of the surface, but in a piece of cloth they are physical entities the form of which is related to, and partly determines, the state of stress. Their form is, in fact, of greater importance than that of the surface itself, since they are in a very practical sense the units out of which it is built.

The present paper, which is intended as the first step in a general treatment of the stress-strain relationships of cloth, gives the general equations of equilibrium of a cloth subject to tensions at its edges and a hydrostatic pressure normal to its surface, and describes their application to a simple problem, that of a circular cylinder of cloth subjected to tension at its ends.

The many simplifying assumptions which have to be made in order to reduce the equations to a tractable form may be set down here. The cloth is assumed to be a thin lamina composed of uniform perfectly flexible and inextensible threads of cylindrical cross-section. It is also assumed that the structure of the cloth varies slowly, i.e., that the variations in the structure of the cloth due to the stress are small and continuous between adjacent elements. A further assumption is that the cloth is incapable of supporting shear, and thus the only forces to be considered are the tensions in the threads themselves. These assumptions may seem to rob the cloth of many of its characteristic properties and the forms assumed by such a structure will certainly differ from those assumed by actual cloth, but it is only by developing the theory for a simple model that the complicating effects of other properties, such as the elasticity, frictional properties and compressibility of the threads, may be separated out by the comparison of theory and experiment. It should then be possible for the theory to take account of these by suitable approximations. It is hoped also that the theory will provide a stimulus to more detailed experimental work.

A few words about the notation employed may not be out of place here. Vectors are used wherever possible, and as far as geometry is concerned, the notation of Weatherburn's " *Differential Geometry of Three Dimensions* " (2 vols., Cambridge, 1930) is used, and for cloth constants, that of F. T. Peirce.[1] Since references to Weatherburn's book will be frequent, they will be given in the text and not at the end of the paper, thus " W., I, 41 " will denote " Weatherburn, Vol. I, page 41."

2. DEFINITIONS AND NOTATION—SOME FUNDAMENTAL MAGNITUDES OF THE CLOTH SURFACE

A full discussion of the unit cell and its application to practical problems of cloth design has been given by Peirce[1] but the notation and fundamental equations are repeated here for the sake of completeness. The following list of definitions gives the notation, the suffix 1 being used for quantities relating to the warp, and the suffix 2 for quantities relating to the weft. Fig. 1 helps to make clear the way in which the various quantities are related to one another.

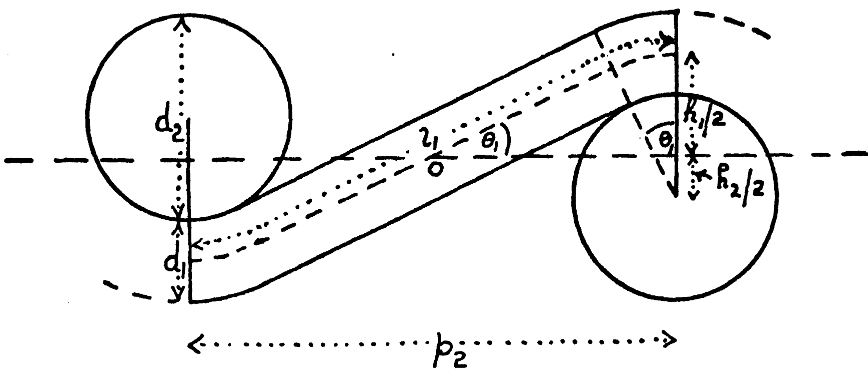


Fig. 1

Diameter of warp, d_1; Diameter of weft, d_2; $d_1+d_2=D$.
Distance between central planes of adjacent warp threads, p_1.
,, ,, ,, ,, ,, ,, weft ,, p_2.
Distance of centres of warp threads from centre-line of cloth, $h_1/2$.
,, ,, ,, weft ,, ,, ,, ,, $h_2/2$.
Inclination of warp threads to centre-line of cloth, θ_1.
,, weft ,, ,, ,, ,, θ_2.
Length of warp between two adjacent weft threads, l_1.
,, weft ,, ,, warp ,, l_2.

Warp crimp, $c_1 = \dfrac{l_1}{p_2} - 1$.

Weft crimp, $c_2 = \dfrac{l_2}{p_1} - 1$.

We then have, by projection in and perpendicular to the plane of the cloth,

$$h_1=\left\{l_1-(d_1+d_2)\,\theta_1\right\}\sin\theta_1+(1-\cos\theta_1)\,(d_1+d_2) \quad \ldots \quad (1.1)$$

$$p_2=\left\{l_1-(d_1+d_2)\,\theta_1\right\}\cos\theta_1+\sin\theta_1 \quad \ldots \quad \ldots \quad \ldots \quad (1.2)$$

and similarly for h_2 and p_1.

As in Peirce's paper, d_1+d_2, the sum of the diameters of the threads, is chosen as the unit of measurement.

We then write

$$h_1=(l_1-\theta_1)\sin\theta_1+(1-\cos\theta_1) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2.1)$$

$$p_2=(l_1-\theta_1)\cos\theta_1+\sin\theta_1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2.2)$$

It will also be seen from Fig. 1 that $h_1+h_2=1$. These are the fundamental relations between the constants of the cloth.

The values of p_1 and p_2 for the original state of the cloth, which are constants, will be denoted by p_{10} and p_{20}. Since the values of l_1 and l_2 will be unchanged under stress if the threads are assumed to be inextensible, these will be constants, but p_1 and p_2 will vary from place to place in the cloth,

their values being related by equations 2.1 and 2.2 and the relation $h_1+h_2=1$. Thus we can write $p_2=f(p_1, l_1, l_2)$, if we imagine the equations solved after eliminating θ_1, θ_2, h_1, h_2. This cannot be done algebraically, but tables of this function can be compiled by inverting the fundamental tables. The necessary tables for the construction of this function for any particular cloth are given in Section 6, together with an explanation of the appropriate method.

When the cloth is in the deformed state, the threads themselves will be taken as parametric curves. In other words, the warp threads will be the curves v=const., and the weft threads will be the curves u=const. so that u varies along the warp, whilst v varies along the weft. Consider the element of cloth surface enclosed by the four curves

u=const., $u+\delta u$=const., v=const. and $v+\delta v$=const.

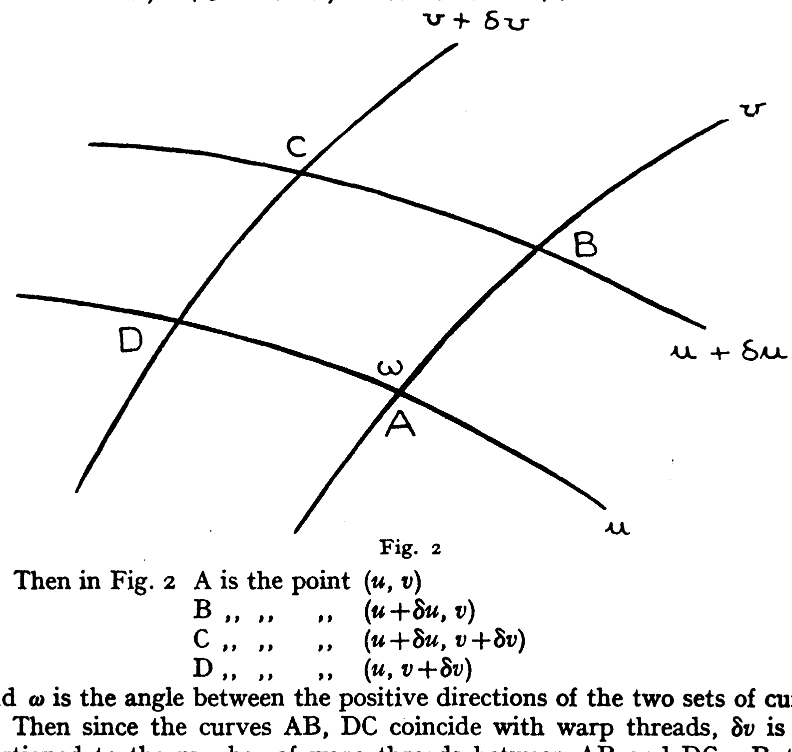


Fig. 2

Then in Fig. 2 A is the point (u, v)

B ,, ,, ,, $(u+\delta u, v)$

C ,, ,, ,, $(u+\delta u, v+\delta v)$

D ,, ,, ,, $(u, v+\delta v)$

and ω is the angle between the positive directions of the two sets of curves.

Then since the curves AB, DC coincide with warp threads, δv is proportioned to the number of warp threads between AB and DC. But the distance between successive warp threads is p_1, hence along the curves u =const.,

$$ds = p_1 dv.$$

Similarly along the curves v =const.

$$ds = p_2 du.$$

Hence the equation for the line-element of the surface is

$$ds^2 = p_2^2\, du^2 + 2p_1\, p_2 \cos \omega\, du\, dv + p_1^2\, dv^2 \quad \ldots \quad \ldots \quad \ldots \quad (2.3)$$

where it must be remembered that p_1 and p_2 are not independent, but are related by the function tabulated in Section 6. Thus p_1 and p_2 are related to the fundamental magnitudes of the surface (W,I, p. 51). The area of the small element of area ABCD is

$$p_1\, p_2 \sin \omega\, \delta u\, \delta v \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2.4)$$

Since p_2 and p_1 are related, it follows from (2.3) and Bonnet's theorem (W, I, p. 95) that in order to determine the cloth-surface uniquely it is only necessary to specify p_1 and ω as functions of u and v. It will be shown later that this places restrictions on the possible deformations of the surface.

One further relation must be derived from the properties of the unit cell, before considering the general equation of equilibrium. Owing to the interlacing of the warp and weft there must be a relation between the tensions in the two sets of threads. If the threads are perfectly flexible, this is seen from Fig. 1 to be

$$T_1 \sin \theta_1 = T_2 \sin \theta_2$$

if T_1 and T_2 are the tensions in warp and weft threads respectively. If the components of T_1 and T_2 *in the plane of the cloth* are F_1 and F_2, then

$$F_1 \tan \theta_1 = F_2 \tan \theta_2$$

i.e. $$F_2 = F_1 \frac{\tan \theta_1}{\tan \theta_2}$$

Now in virtue of the fundamental equations 2.1 and 2.2 we may write the right-hand side of this as a function of l_1, l_2 and p_1. Let us write

$$F_2 = \chi F_1 \qquad \ldots \qquad (2.5)$$

The method of constructing $\chi(p_1, l_1, l_2)$ for any given cloth is given in Section 6 of this paper. Thus when p_1 is known as a function of u and v, the ratio is everywhere determined. This also gives a condition that the cloth surface must satisfy.

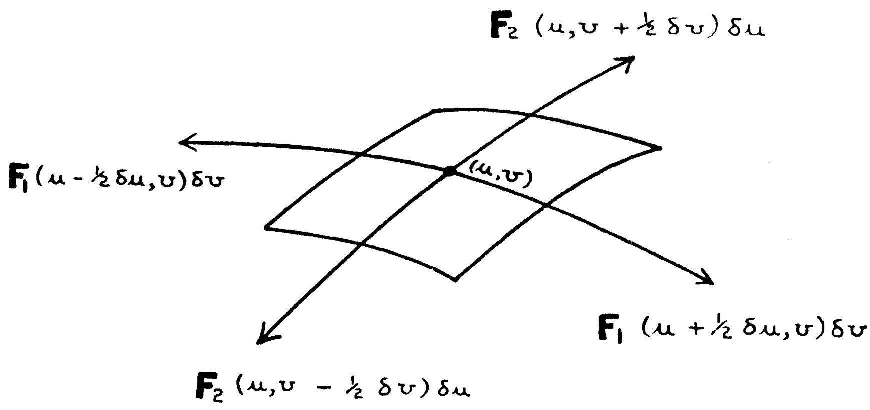


Fig. 3

3. THE EQUATIONS OF EQUILIBRIUM OF A CLOTH SUBJECT TO TENSIONS AT ITS EDGES AND A NORMAL HYDROSTATIC PRESSURE

The primary assumptions in this section are that the cloth is incapable of supporting shear i.e., that the only forces to be considered are the tensions in the threads, that the crossing places in the threads are fixed as far as the threads themselves are concerned (no "fraying") and that the changes in shape of the surface as u and v vary are slow compared with the size of the unit cell. This is the corresponding assumption to that of "physical smallness" in other branches of mathematical physics. It assumes that an "infinitesimal element" from the point of view of curvature and other surface properties still contains a large number of unit cells. It may be noted that the form of the equations of equilibrium does not depend on the

assumption of inextensibility and flexibility of the threads, but only on the absence of shear and fineness of structure.

Consider the equilibrium of a small element of cloth bounded by the curves $u - \frac{1}{2}\delta u$, $u + \frac{1}{2}\delta u$, $v - \frac{1}{2}\delta v$, $v + \frac{1}{2}\delta v$. Then if $\mathbf{F}_1\,(u, v)$ is the tension per thread in the warp-direction of the cloth at the point (u, v) and $\mathbf{F}_2(u, v)$ is the corresponding tension in the weft-direction, the forces acting on the cloth will be those shown in Fig. 3.

If $\mathbf{P}$ is the normal hydrostatic pressure per unit area of the surface, and δS is the area of the element, the force on the element is $\mathbf{P}\delta S$, and since this is balanced by the tensions in the threads, we must have

$$\begin{aligned}&\mathbf{F}_1(u + \tfrac{1}{2}\delta u, v)\delta v - \mathbf{F}_1(u - \tfrac{1}{2}\delta u, v)\delta v \\ &+ \mathbf{F}_2(u, v + \tfrac{1}{2}\delta v)\delta u - \mathbf{F}_2(u, v - \tfrac{1}{2}\delta v)\delta u = \mathbf{P}\delta S\end{aligned}$$

Now if $\boldsymbol{n}$ is a unit vector normal to the surface at the point (u, v), $\mathbf{P} = P\boldsymbol{n}$.

On putting in the value of δS from 2.4, the equation for the equilibrium of the cloth-element becomes

$$\begin{aligned}&\mathbf{F}_1(u + \tfrac{1}{2}\delta u, v)\delta v - \mathbf{F}_1(u - \tfrac{1}{2}\delta u, v)\delta v + \mathbf{F}_2(u, v + \tfrac{1}{2}\delta v)\delta u \\ &\quad - \mathbf{F}_2(u, v - \tfrac{1}{2}\delta v)\delta u - P\boldsymbol{n}p_1p_2 \sin\theta\delta u\delta v = 0\end{aligned}$$

Now $$\mathbf{F}_1(u + \tfrac{1}{2}\delta u, v) - \mathbf{F}_1(u - \tfrac{1}{2}\delta u, v) = \frac{\partial \mathbf{F}_1}{\partial u}\,\delta u$$

$$\mathbf{F}_2(u, v + \tfrac{1}{2}\delta v) - \mathbf{F}_2(u, v - \tfrac{1}{2}\delta v) = \frac{\partial \mathbf{F}_2}{\partial v}\,\delta v$$

Hence

$$\frac{\partial \mathbf{F}_1}{\partial u} + \frac{\partial \mathbf{F}_2}{\partial v} - P\boldsymbol{n}p_1p_2 \sin\omega = 0 \quad \dots \quad (3.1)$$

Now let $\boldsymbol{a}$, $\boldsymbol{b}$, be unit vectors in the direction of the warp and weft respectively. Then $\boldsymbol{a}$, $\boldsymbol{b}$, and $\boldsymbol{n}$ form a right-handed system. The vector equation of equilibrium can now be resolved into three scalar equations by multiplying in turn by $\boldsymbol{a}\cdot$, $\boldsymbol{b}\cdot$, and $\boldsymbol{n}\cdot$.

We may also write

$$\begin{aligned}\mathbf{F}_1 &= F_1\boldsymbol{a} \\ \mathbf{F}_2 &= F_2\boldsymbol{b} \quad \dots \quad \dots \quad \dots \quad \dots \quad (3{\cdot}2)\end{aligned}$$

and the equations then become

$$\frac{\partial F_1}{\partial u} + \boldsymbol{a}\cdot\boldsymbol{b}\frac{\partial F_2}{\partial v} + F_2\boldsymbol{a}\cdot\frac{\partial \boldsymbol{b}}{\partial v} = 0 \quad \dots \quad \dots \quad \dots \quad \dots \quad (3{\cdot}3)$$

$$\frac{\partial F_2}{\partial v} + \boldsymbol{a}\cdot\boldsymbol{b}\frac{\partial F_1}{\partial u} + F_1\boldsymbol{b}\cdot\frac{\partial \boldsymbol{a}}{\partial u} = 0 \quad \dots \quad \dots \quad \dots \quad \dots \quad (3{\cdot}4)$$

and

$$F_2\boldsymbol{n}\cdot\frac{\partial \boldsymbol{b}}{\partial v} + F_1\boldsymbol{n}\cdot\frac{\partial \boldsymbol{a}}{\partial u} = Pp_1p_2 \sin\omega \quad \dots \quad \dots \quad \dots \quad (3{\cdot}5)$$

Now $\boldsymbol{n}\cdot\dfrac{\partial \boldsymbol{a}}{\partial u} = p_2\kappa_1$, where κ_1 is the curvature of a normal section of the surface taken along the tangent to the curve $v = \text{const}$. Similarly

$$\boldsymbol{n}\cdot\frac{\partial \boldsymbol{b}}{\partial v} = p_1\kappa_2$$

and thus the third of the above equations becomes

$$F_2p_1\kappa_2 + F_1p_2\kappa_1 = Pp_1p_2 \sin\omega.$$

The similarity of this to the equation of equilibrium of a soap film will be apparent.

If the surface were a plane, the quantities $\mathbf{b}.\frac{\partial \mathbf{a}}{\partial u}$ and $\mathbf{a}.\frac{\partial \mathbf{b}}{\partial v}$ would be related to the curvatures of the u and v curves by the relations

$$\mathbf{b}.\frac{\partial \mathbf{a}}{\partial u} = \frac{p_2}{\rho_1} \sin \omega \quad \ldots \quad (3.6)$$

$$\mathbf{a}.\frac{\partial \mathbf{b}}{\partial v} = -\frac{p_1}{\rho_2} \sin \omega \quad \ldots \quad (3.7)$$

where ρ_1 and ρ_2 would be the radii of curvature of the u and v curves. When the surface is not plane, ρ_1 and ρ_2 become the radii of curvature in the direction of the tangent plane, i.e., the radii of geodesic curvature (W, I, 108). It is usual to denote the geodesic curvatures of the two sets of curves by γ and γ'. The equations of equilibrium thus become, after inserting these values for the coefficients and also $F_2 = \chi F_1$,

$$\frac{\partial F_1}{\partial u} + \cos \omega \frac{\partial}{\partial v}(\chi F_1) - \chi F_1 \gamma' p_1 \sin \omega = 0 \quad \ldots \quad (3.8)$$

$$\cos \omega \frac{\partial F_1}{\partial u} + \frac{\partial}{\partial v}(\chi F_1) + F_1 \gamma p_2 \sin \omega = 0 \quad \ldots \quad (3.9)$$

$$F_1\left(\frac{\kappa_1}{p_1} + \chi \frac{\kappa_2}{p_2}\right) = P \sin \omega \quad \ldots \quad (3.10)$$

In these equations, χ and p_2 are known functions of p_1 (see 2.5) and hence the three equations of equilibrium involve three unknowns, F_1, p_1 and ω, κ_1, κ_2 and γ, γ' being related to p_1, p_2 and ω. Now, since these relations will be complicated in form, there is little hope of obtaining a general solution of the equations, but further light on the possibility of solving them can be obtained by throwing them into an alternative form in which the coefficients are the fundamental magnitudes of the surface and their derivatives.

In what follows the suffixes 1 and 2 will denote differentiations with respect to u and v except for F_1 and F_2, which retain their meaning. The relations (3.2) are replaced by

$$\mathbf{F}_1 = R\mathbf{r}_1$$
$$\mathbf{F}_2 = S\mathbf{r}_2 \quad \ldots \quad (3.11)$$

R and S thus represent tension per unit width of the cloth. On inserting these relations, equation (3.1) becomes

$$R\mathbf{r}_{11} + R_1\mathbf{r}_1 + S\mathbf{r}_{22} + S_2\mathbf{r}_2 - P\mathbf{n}H = 0 \quad \ldots \quad (3.12)$$

since $p_1 p_2 \sin \omega = H$ (W., I, 54)

Scalar multiplication of (3.12) by $\mathbf{n}$, $\mathbf{r}_1$, $\mathbf{r}_2$, in turn gives, in the usual notation (W., I, 90)

$$R\frac{L}{H} + S\frac{N}{H} = P \quad \ldots \quad (3.13)$$

$$ER_1 + FS_2 + \tfrac{1}{2}E_1R + (F_2 - \tfrac{1}{2}G_1)S = 0 \quad \ldots \quad (3.14)$$

$$FR_1 + GS_2 + (F_1 - \tfrac{1}{2}E_2)R + \tfrac{1}{2}G_2S = 0 \quad \ldots \quad (3.15)$$

Now since $E = p_2^2$, $G = p_1^2$, we may regard G as a known function of E, and we shall also have $S = \Psi R$ where $\Psi = \frac{p_2}{p_1}\chi$, and therefore Ψ may be regarded as a function of E alone.

Thus, as before, there are three equations with three unknowns E, F and R. It is known, however (W., I, 90 et seq.) that the fundamental magnitudes of the second order, L, M, N cannot be expressed directly as functions of the fundamental magnitudes of the first order E, F, G, but

that there exist three differential relations connecting them, the Mainardi-Codazzi relations and the Gauss characteristic equation.

It will not be possible, therefore, to solve any problems directly, unless considerations of symmetry or other restrictions on the form of solution simplify the equations considerably. On the other hand, if the surface and the form of the threads are regarded as given, the three equations of equilibrium define the tensions in warp and weft direction which will keep it in the given form. If these are statically equivalent to the forces on the cloth in some problem of practical interest one may hope that the form of the cloth may be similar in the two problems. It may be pointed out that certain general relations between the fundamental magnitudes can be deduced from the general equations by eliminating the tensions. These are conditions that all deformations of the cloth must satisfy. Thus, on multiplying equation (3.9) by cos ω and subtracting from (3.8) we have

$$\sin^2\omega\frac{\partial F_1}{\partial u}-\chi F_1\ \gamma'\ p_1\sin\omega-F_1\ \gamma\ p_2\sin\omega\cos\omega=0.$$

Hence $\dfrac{1}{F_1}\dfrac{\partial F_1}{\partial u}=\chi\ \gamma'\ p_1\operatorname{cosec}\omega+\gamma\ p_2\cot\omega$ ... ... (3.16)

and similarly, on multiplying (3.8) by cos ω and subtracting from (3.9)

$$\frac{1}{F_2}\frac{\partial F_2}{\partial v}=-\frac{1}{\chi}\ \gamma\ p_2\operatorname{cosec}\omega-\gamma' p_1\cot\omega \quad \dots \quad \dots \quad \dots \quad (3.17)$$

Now $\dfrac{1}{F_2}\dfrac{\partial F_2}{\partial v}=\dfrac{\partial}{\partial v}(\log F_2)=\dfrac{\partial}{\partial v}(\log\chi)+\dfrac{\partial}{\partial v}(\log F_1)$

Hence, on differentiating (3.16) with respect to v and (3.17) with respect to u, we have

$$\frac{\partial^2}{\partial u\,\partial v}(\log\chi)+\frac{\partial}{\partial v}(\chi\,\gamma' p_1\operatorname{cosec}\omega)+\frac{\partial}{\partial v}(\gamma p_2\cot\omega)$$
$$+\frac{\partial}{\partial u}\left(\frac{1}{\chi}\gamma p_2\operatorname{cosec}\omega\right)+\frac{\partial}{\partial u}(\gamma' p_1\cot\omega)=0 \quad \dots \quad \dots \quad (3.18)$$

In effect, this gives a relation which p_1 and ω must satisfy, whatever the tension-distribution may be, if the deformation is to be possible. Thus, in finding the tensions produced in a cloth by a given deformation, it is necessary to see if the above equation is satisfied, for otherwise the deformation is not possible. When the appropriate tensions have been found, the equation

$$F_1\left(\frac{\kappa_1}{p_1}+\chi\frac{\kappa_2}{p_2}\right)=P\sin\omega$$

defines P as a function of u and v. This is the normal pressure required to keep the system in equilibrium. A similar equation to (3.18) may also be obtained, by eliminating R and S from equations (3.14) and (3.15).

When the cloth surface is a plane, equation (3.10) disappears, and we are, apparently, left with fewer equations than unknowns. The other equations, expressing the fact that the surface is a plane can be supplied in the following way: Since the surface is a plane, any point on it has its position defined by its cartesian co-ordinates (x, y). Moreover, since also each point is defined when the warp and weft threads on which it lies are known,

$$x=f(u,v)$$
$$y=g(u,v)$$

The elimination of v between these equations gives the cartesian equations of the weft threads, and the elimination of u gives the cartesian equations of the warp threads.

Now let ψ_1 be the angle between the tangent to the warp threads and the x-axis, amd let ψ_2 be the angle between the weft threads and the y-axis, assuming that before the cloth was deformed the x-axis lay along the warp threads and the y-axis along the weft threads. This is done so that in certain circumstances it may be possible to assume ψ_1 and ψ_2 are small.

Then $$\omega=\frac{\pi}{2}+(\psi_2-\psi_1) \qquad \ldots \quad (3.19)$$

and also $$\frac{\partial x}{\partial u}=p_2\cos\psi_1,\ \frac{\partial y}{\partial u}=p_2\sin\psi_1 \qquad \ldots \quad (3.20)$$

$$\frac{\partial x}{\partial v}=-p_1\sin\psi_2,\ \frac{\partial y}{\partial v}=p_1\cos\psi_2 \qquad \ldots \quad (3.21)$$

Now for any plane curve $\dfrac{1}{\rho}=\dfrac{d\psi}{ds}$

Hence $$\left.\begin{aligned} p_2\gamma &= \frac{\partial\psi_1}{\partial u} \\ p_1\gamma' &= \frac{\partial\psi_2}{\partial v} \end{aligned}\right\} \qquad \ldots \quad (3.22)$$

From (3.20) and (3.21)

$$\frac{\partial}{\partial v}(p_2\cos\psi_1)=-\frac{\partial}{\partial u}(p_1\sin\psi_2) \qquad \ldots \quad (3.23)$$

$$\frac{\partial}{\partial v}(p_2\sin\psi_1)=\frac{\partial}{\partial u}(p_1\cos\psi_2) \qquad \ldots \quad (3.24)$$

The general equations may be written, in virtue of (3.19) and (3.22) as

$$\frac{\partial F_1}{\partial u}-\sin(\psi_2-\psi_1)\frac{\partial F_2}{\partial v}-F_2\frac{\partial\psi_2}{\partial v}\cos(\psi_2-\psi_1)=0 \qquad \ldots \quad (3.25)$$

$$-\sin(\psi_2-\psi_1)\frac{\partial F_1}{\partial u}+\frac{\partial F_2}{\partial v}+F_1\frac{\partial\psi_1}{\partial u}\cos(\psi_2-\psi_1)=0 \qquad \ldots \quad (3.26)$$

This gives four equations to determine the four unknowns

F_1 p_1, ψ_1 and ψ_2.

The result of eliminating the tensions between these equations may also be given. It is

$$\frac{\partial^2}{\partial u\partial v}(\log\chi)+\frac{\partial}{\partial u}\left\{\frac{1}{\chi}\sec(\psi_2-\psi_1)\frac{\partial\psi_1}{\partial u}\right\}-\frac{\partial}{\partial u}\left\{\tan(\psi_2-\psi_1)\frac{\partial\psi_2}{\partial v}\right\}$$
$$+\frac{\partial}{\partial v}\left\{\chi\sec(\psi_2-\psi_1)\frac{\partial\psi_2}{\partial v}\right\}-\frac{\partial}{\partial v}\left\{\tan(\psi_2-\psi_1)\frac{\partial\psi_1}{\partial u}\right\}=0 \qquad (3.27)$$

This is not simple enough to be of real use in practical problems. It is hoped, however, that problems in which ψ_1 and ψ_2 are both small may be of practical importance, for then the system is simplified considerably, since on writing $\cos\psi_1 \doteqdot 1$, $\cos\psi_2 \doteqdot 1$, $\sin\psi_2 \doteqdot \psi_2$, $\sin\psi_1 \doteqdot \psi_1$ and neglecting terms of the second order, the equations become

$$\frac{\partial p_2}{\partial v}=-\frac{\partial}{\partial u}(p_1\psi_2) \qquad \ldots \quad (3.28)$$

$$\frac{\partial p_1}{\partial u}=\frac{\partial}{\partial v}(p_2\psi_1) \qquad \ldots \quad (3.29)$$

and $$\frac{\partial^2}{\partial u\partial v}(\log\chi)+\frac{\partial}{\partial u}\left\{\frac{1}{\chi}\frac{\partial\psi_1}{\partial u}\right\}+\frac{\partial}{\partial v}\left\{\chi\frac{\partial\psi_2}{\partial v}\right\}=0 \qquad \ldots \quad (3.30)$$

4. BOUNDARY CONDITIONS

Before studying boundary conditions in detail, it is first necessary to consider which conditions of use or test are likely to lead to tractable problems. The simplest problem of all, a circular cylinder of cloth extended by tension at its ends, is solved in the next section. This does not correspond to any standard test, but merits treatment by reason of its mathematical simplicity. Another problem of importance is that of a piece of cloth, clamped along one edge, to which tension is applied at a single point on the other edge. This corresponds with the " point source " in hydrodynamics, or the " point charge " in electrostatics, and is also of practical importance since it represents to some extent the distribution of stress round a tent guy-rope. Other systems of plane stress that are of importance are the flat strip of cloth gripped at its ends and subjected to tension, and an infinite piece of cloth, a small portion in the centre of which is subjected to tension between grips. These correspond respectively to the standard tensile test for cloth and to the " grab " test. If one considers the kinds of stress to which clothes are subjected in use, the distribution of tension in a sample of cloth forced to

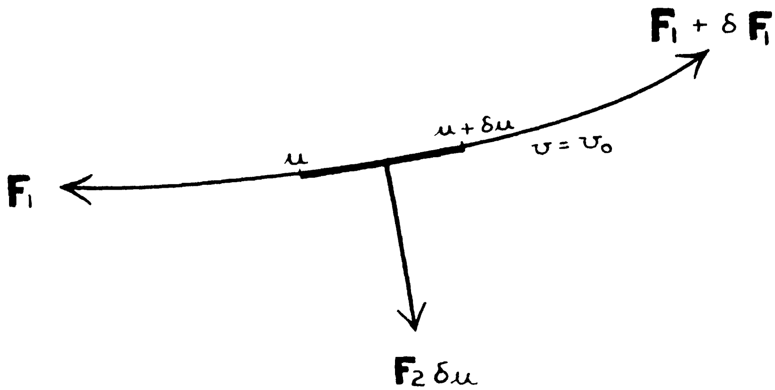


Fig. 4.

conform to a given surface is seen to be of importance. The special case of this, where the surface is a sphere, might, therefore, be a possible problem for theoretical treatment, though further complications would arise in taking account of the extensibility of the threads. Further development of the subject beyond the simple problem solved in the present paper seems, therefore, to fall into two parts, the study of systems of plane stress, and the working out of the form of the threads and the distribution of tensions when the cloth is forced to conform to a given surface. It is hoped to deal with these topics in future papers.

Consideration of the above list of problems shows that boundaries are of two kinds—free edges, which may be taken to be warp or weft threads, and clamped edges, at which tension is applied to the cloth, which may or may not coincide with the warp or weft threads. These two kinds of boundary will be considered in turn.

Let the warp thread $v = v_0$ be a free edge. Then along this free edge if it is to be in equilibrium

$$\delta F_1 = F_2 \delta u$$

Thus along the free edge $v = v_0$

$$\mathbf{F}_2 = \frac{\partial \mathbf{F}_1}{\partial u}$$

$$\therefore F_2 b = \frac{\partial F_1}{\partial u} a + F_1 \frac{\partial a}{\partial u}$$

Resolving

$$F_2 \cos \omega = \frac{\partial F_1}{\partial u} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4.1)$$

$$F_2 = \frac{\partial F}{\partial u} \cos \omega + F_1 p_2 \gamma \sin \omega \quad \ldots \quad \ldots \quad \ldots \quad (4.2)$$

Note that the free edge must be a plane curve, since the threads are perfectly flexible.

On eliminating F_2 between (4.1) and (4.2), and solving for F_1 we have

$$F_1 = Ce^{\int p_2 \gamma \cot \psi du} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4.3)$$

and also $\chi = p_2 \gamma \operatorname{cosec} \omega$ ... ... (4.4)

This is best written $\gamma = \dfrac{\chi}{p_2} \sin \omega$ ... ... (4.5)

When the surface is a plane this reduces to

$$\left(\frac{\partial \psi_1}{\partial u}\right)_{v=v0} = \left\{\chi \cos (\psi_2 - \psi_1)\right\}_{v=v0} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4.6)$$

Consider now a clamped edge which is also a weft thread. This will restrict the spacing of the warp threads to be the same as it was before the forces were imposed, so that at a clamped boundary,

$$p_1 = p_{10}$$
$$p_2 = p_{20}$$

if p_{10} and p_{20} were the original spacings of the threads. This will also be true even if the clamp does not coincide with the threads. The equation to the curve forming the clamp must also be found in terms of the threads as co-ordinates. This may be done by considering the unstrained state of the cloth. If this is a plane, with the threads forming two systems of equidistant and parallel straight lines, the two sets being perpendicular to each other, and the equation of the clamp, before the cloth is deformed, is

$$y = f(x)$$

then, since in the original state of the cloth

$$y = p_1 v, \qquad x = p_2 u$$

we have as the equation of the clamp in terms of the threads as co-ordinates

$$p_1 v = f(p_2 u)$$

Moreover, this equation is unaltered by the deformation of the cloth.

Thus, in the bursting test, in which a piece of cloth is fixed in a circular clamp, and deformed by a uniform hydrostatic pressure, the equation of the circular clamp (taking the origin at the centre of the circle) is

$$p_2^2 u_2 + p_1^2 v^2 = a^2$$

if a is the radius of the circle.

5. THE FORM OF A CIRCULAR CYLINDER OF CLOTH SUBJECT TO TENSION AT ITS ENDS

This problem was chosen first for solution because of its mathematical simplicity, all quantities being functions of one variable. It was also hoped that the solution would at the same time throw light on the much more difficult problem of the flat strip under tension. The problem may be formally stated as follows. A seamless cylinder of cloth of length $2L$ and radius a has its ends fastened in circular clamps, and is extended by a given amount. To find the resulting surface and the tensions in the material. Take the z-axis of cartesian co-ordinates along the axis of the cylinder with its origin mid-way between the two ends. The curves u = const. are circles, with radius r, say. The curves v = const. are plane curves, lying in the system of planes which have the z-axis as a common line.

The equation for the form of the cloth is

$$\begin{aligned} x &= r\cos\varphi \\ y &= r\sin\varphi \\ z &= f(r) \end{aligned} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.1)$$

Then we wish to know the form of $f(r)$, the radius at the mid-section of the cylinder, and the tensions in the cloth at every point.

The u, v system of co-ordinates is everywhere orthogonal and therefore $\cos\omega = 0$, so that the equation for the line-element is

$$ds^2 = p_2^2du^2 + p_1^2dv^2 \qquad \ldots \quad \ldots \quad \ldots \quad (5.2)$$

Now at $r = a$, p_1 is the same as it was in the original state of the cloth, and therefore, if the initial values of p_1 and p_2 were p_{10} and p_{20}

$$\frac{p_1}{p_{10}} = \frac{r}{a} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.3)$$

since there are the same number of threads in the cloth as there were before the tension was applied to the cloth.

By symmetry, F_1 and F_2 must be independent of v, and therefore $\frac{\partial F_1}{\partial v} = \frac{\partial F_2}{\partial v} = 0$. This condition, together with the condition $\cos\omega = 0$, reduces the general equations to

$$\frac{\partial F_1}{\partial u} - \chi F_1 p_1 \gamma' = 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.4)$$

$$F_1 p_2 \gamma \quad = 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.5)$$

$$\frac{\kappa_1}{p_1} + \chi\frac{\kappa_2}{p_2} \quad = 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.6)$$

Equation (5.5) shows that $\gamma = 0$, i.e., the u-curves have no curvature in the tangent plane to the surface, as one would expect. Equation (5.6) does not involve F_1 and therefore gives the geometrical form of the surface.

Let the tangent plane at any point of the surface make an angle ψ with the z-axis.

Then $\kappa_1 = \frac{d\psi}{ds} = \frac{1}{p_2}\frac{d\psi}{du}$

and since the v-curve through the same point is a circle of radius r perpendicular to the z-axis, we have

$$\kappa_2 = \frac{1}{r\cos\psi}$$

To find γ' we must find the curvature of the projection of this circle on the tangent-plane. This is an ellipse of semi-axes r, $r \sin \psi$. The radius of curvature of an ellipse at the ends of the minor axis is, by the usual formula

$$\rho = \frac{a}{\sqrt{1-e^2}}$$

if a is the semi-major axis and e the eccentricity.
For the ellipse with semi-axes, r, $r \sin \psi$ this reduces to

$$\rho = r \operatorname{cosec} \psi.$$

Hence

$$\frac{dF_1}{du} - p_1 \frac{\sin \psi}{r} \chi F_1 = 0 \ldots \qquad (5.7)$$

But (5.6) becomes, after inserting the values of κ_1 and κ_2

$$\frac{d\psi}{du} = \frac{\chi p_1}{r \cos \psi}$$

κ_1 and κ_2 being of opposite sign, since the surface is anticlastic. Thus (5.7) becomes

$$\frac{dF_1}{du} - F_1 \sin \psi \cos \psi \frac{d\psi}{du} = 0 \ldots \qquad (5.9)$$

on inserting the value of χ from (5.8).

Solving (5.9)

$$F_1 = Ce^{\frac{1}{2} \sin^2 \psi}.$$

To find the value of C suppose that F_1 has the value F_{10} at the end of the cylinder, i.e., when $r=a$ and that $\psi=\psi_0$ at this point. Then

$$F_{10} = Ce^{\frac{1}{2} \sin^2 \psi_0}$$

i.e.,

$$F_1 = F_{10}\, e^{\frac{1}{2} (\sin^2 \psi_0 - \sin^2 \psi)}$$

If $r=r_0$ at the central section of the cylinder, and $F_1 = F_1(r_0)$ at this point,

$$F_1 = F_1(r_0).e^{\frac{1}{2} \sin^2 \psi}$$

Thus the maximum tension in the material is at the grip.

To find the form of the surface, consider equation (5.8).

We have $\cos \psi \dfrac{d\psi}{du} = p_1 \chi$.

This may be written

$$\frac{d}{ds} (\sin \psi) = \frac{p_1}{p_2} \chi$$

Now p_1 is a known function of r (5.3) and thus the right-hand side of this equation is a known (tabular) function of r when any particular cloth is specified. Then, since $\sin \psi = \dfrac{dr}{ds}$ the equation may be written

$$\frac{d^2 r}{ds^2} = \varphi(r) \ldots \qquad (5.10)$$

which is an integrable form. Writing $w = \dfrac{dr}{ds} = \sin \psi$ it becomes

$$w \frac{dw}{dr} = \varphi(r).$$

Hence

$$\tfrac{1}{2}\sin^2\psi = \frac{w_2}{2} = \int_{r_0}^{r} \varphi(r)\, dr.$$

Thus the first quadrature gives the quantity required in the expression for the tension.

Now $\dfrac{dr}{dz} = \tan\psi$.

Thus

$$\left(\frac{dr}{dz}\right)^2 = \frac{\sin^2\psi}{\cos^2\psi} = \frac{2\displaystyle\int_{r_0}^{r} \varphi(r)\, dr}{1 - 2\displaystyle\int_{r_0}^{r} \varphi(r)\, dr.}$$

Hence the form of the curve may be obtained by a second quadrature. It is more convenient in practice, instead of attempting the second quadrature, to solve equation (5.10) numerically by the method described by

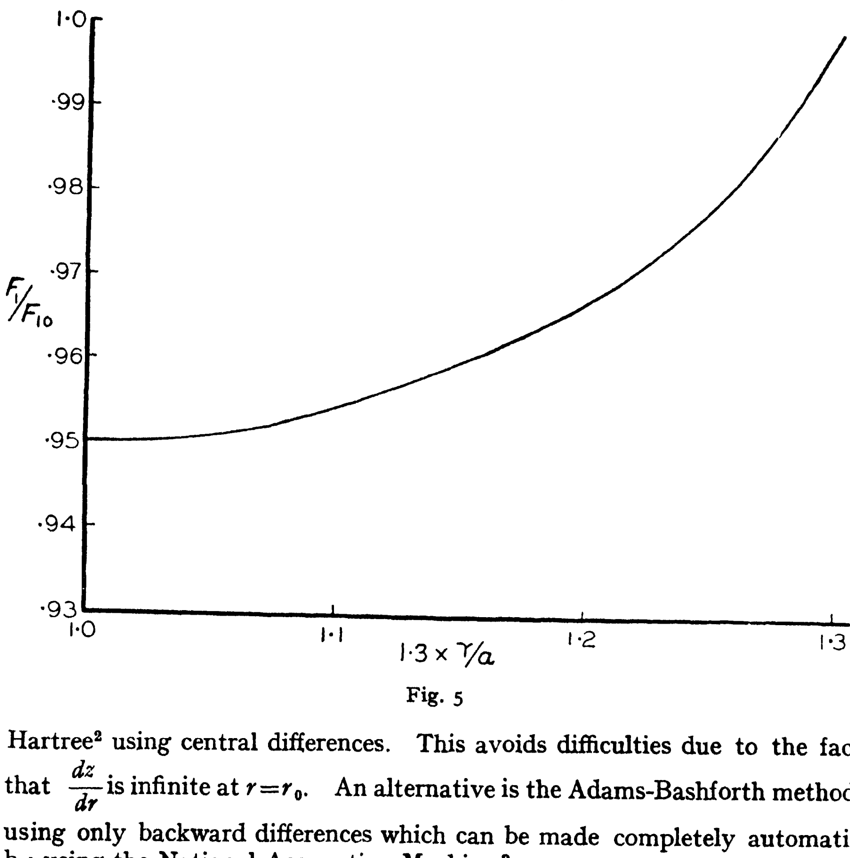


Fig. 5

Hartree[2] using central differences. This avoids difficulties due to the fact that $\dfrac{dz}{dr}$ is infinite at $r=r_0$. An alternative is the Adams-Bashforth method using only backward differences which can be made completely automatic by using the National Accounting Machine.[3]

Since no experimental results are available for the cloth cylinder and the possible structures form a doubly-infinite set it seems unnecessary to work out numerical results for a wide range of cloths. Instead, a typical solution is given for one cloth only, as an illustration of the way in which the tables of section 6 are used.

Consider a cloth in which

$l_1 = 1{\cdot}6$	$p_{10} = 1{\cdot}3$	$C_{10} = 5{\cdot}96\%$
$l_2 = 1{\cdot}4$	$p_{20} = 1{\cdot}51$	$C_{20} = 7{\cdot}7\%$

Table I in the paper by Peirce (facing page T58) gives h as a function of l and $l-p$. Entering this table at the column $l = 1{\cdot}4$, the values of h_2 corresponding to a set of equidistant values of p_1 are written down. Subtracting these from unity gives the corresponding values of h_1, and entering the column $l = 1{\cdot}6$, the corresponding values of p_2 are written down. This gives p_2 as a function of p_1, and hence of $\dfrac{r}{a}$. A corresponding Table in Section 6 gives θ as a function of l and $l-p$, and entering this in the appropriate columns, both tan θ_1, and tan θ_2 are obtained from standard tables, and thence χ as a function of $\dfrac{r}{a}$.

For the numerical integration it is best to throw the equations into non-dimensional form, taking the original radius of the cylinder as the unit of length.

Let $\quad R = \dfrac{r}{a}, \; Z = \dfrac{z}{a} \quad$ Then

$$w\frac{dw}{dr} = \frac{p_{10}}{p_2}\chi$$

and

$$\left(\frac{dR}{dZ}\right)^2 = \frac{2\displaystyle\int_{R_0}^{R}\frac{p_{10}}{p_2}\chi dR}{1 - 2\displaystyle\int_{R_0}^{R}\frac{p_{10}}{p_2}\chi dR}$$

The particular solution which has been worked out is for a decrease in the central radius of the cylinder of 23·1 per cent., p_1 at this section falling from its original value 1·3 to 1·0. The first integration, which gives $\frac{1}{2}\sin^2\psi$, and hence the tension relation, is a simple quadrature.

The result of this first integration is shown in Fig. 5, which gives $\dfrac{F_1}{F_{10}}$ as a function of $1{\cdot}3\dfrac{r}{a}$, i.e. of $\dfrac{r}{r_0}$. The second integration is best done by taking arbitrary initial conditions for the starting first difference of $\dfrac{r}{a}$, and working out the form of the cloth for various lengths of cylinder. A typical curve, for a cylinder whose length is three times its radius, is shown in Fig. 6.

6. THE PREPARATION OF THE TABLES FOR THE CALCULATION OF SPECIFIC SOLUTIONS

The fundamental tables are those of h and p in terms of l and θ. It will will be seen from (2.1) and (2.2) that if θ is constant, h and p are linear functions of l, and the fundamental tables were built up by making use of this fact. An interval of 0·1 in was chosen, and the tables built up by adding the constant first difference to the value of the function already found. Tables of h and l-p were built up in this way with intervals of 0·1 in l and 0·05 in θ. It is more convenient ao use l-p than l, the spread of the tables being reduced, and it is also a convenient quantity from which to calculate the crimp. The quantity l-p strikes a compromise between the

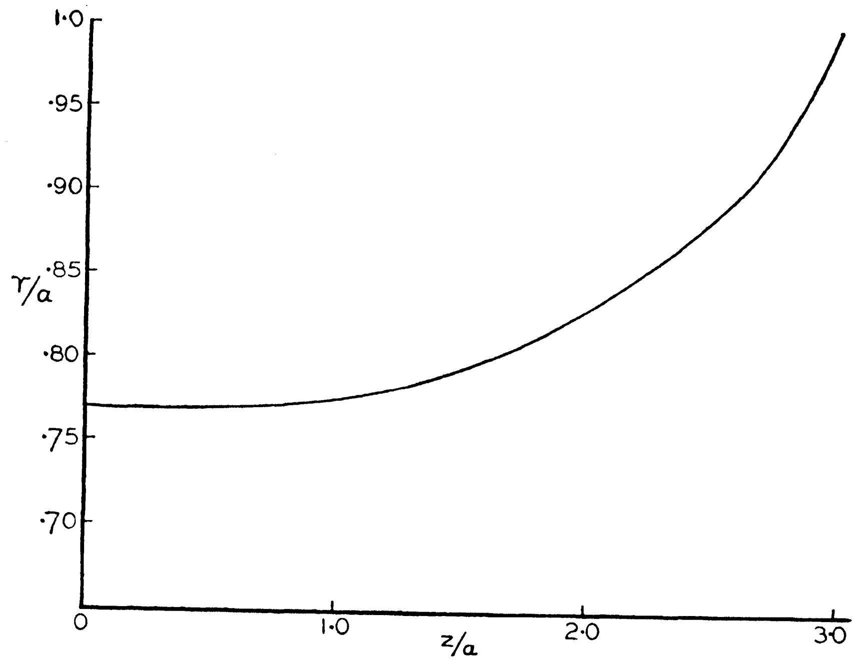


Fig. 6

requirements of the work treated in the present paper, and those of other uses of the tables.[1] The next step was the inversion of these tables to provide two others, h in terms of l and l-p, and θ in terms of l and l-p. For this calculation the method of inverse interpolation due to L. J. Comrie[3] was used, being extended, at Dr. Comrie's suggestion, so as to give both h and θ corresponding to a given value of l-p, at the same time. This was done by placing the first differences of both l-p and h on the right-hand machine, one on the left of the setting-levers and the other on the right. The second differences were similarly placed on the left-hand machine. This method proved invaluable, saving many hours of labour, and also reducing considerably the possibility of error. Table I, giving h in terms of l and l-p, and Table II, recording the limiting values, will be found in the preceding paper (facing page T58). Table III, which gives θ in terms of l and l-p, corresponds exactly to Table I, having the same intervals in both l-p and l, so that interpolations involving θ and h may be done simultaneously, when both are required.

Three figures only are given, and the tables may be interpolated by proportional parts over most of the range. It was felt that greater accuracy than this is unnecessary, in view of the many assumptions made in the theory, and the limited accuracy of most measurements on cloth.

The author wishes to record his thanks to Dr. L. J. Comrie, formerly Superintendent of the Nautical Almanac Office, and to Mr. D. H. Sadler, his deputy, for their advice and help in the preparation of these tables.

REFERENCES

[1] Peirce, F. T. *Preceding communication.*

[2] Hartree, D. R. *Mem. and Proc. Manchester Literary and Philosophical Society,* 1933, **77**, 91.

[3] Comrie, L. J. *Supplement to the Journal of the Royal Statistical Society,* 1936, **3**, 87.

Received 2/3/37

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

7—FLEECE DENSITY OF SHEEP
THE WYEDESA FLEECE CALIPER

By ROBERT H. BURNS, Ph.D. (Edinburgh).

INTRODUCTION

In a former paper by Burns and Miller[1] the terminology of fleece density was discussed. The ultimate use of fleece density is in measuring the amount of clean wool that a sheep will produce. However, sometimes it is not possible to use entire fleeces for analysis, and in such cases it is necessary to devise a technique for measuring the fleece density with samples smaller than the entire fleece. When such measures are desired, it is necessary to know the area of skin from which the samples are taken. With the exception of the side and back body areas, the other samples commonly used for sampling are limited in scope, so that it is necessary to use small samples taken from 1 to 4 square centimetres of skin area.

Fleece density is one of the primary factors in wool production, as has been pointed out in studies of Rambouillet show sheep by Hultz,[2] and Hultz and Paschal.[3]

When measuring fleece density by means of small samples taken from a definite area of skin several methods can be employed. The following have proved most successful :—

1. The number of fibres per unit area of skin.
2. The weight of clean wool per unit of skin.
3. The ratio of fibre cross sectional area to the unit area of skin.

REVIEW OF THE PUBLISHED WORK ON FLEECE DENSITY.

Nathusius[4] was among the first to make a study of fleece density, but he felt that it was both a tedious and difficult problem. He favoured the skin section method over the laborious task of counting the fibres on the skin. He regards his results with skin " shavings " as not too accurate because of the difficulties of focussing his microscope on the sections of skin. He reduced other workers' figures to the same basis and gave the following table of results :—

Number of Fibres per Square Millimetre of Skin Surface :

Common sheep (according to Petri[5])	7·3
Merino (according to Petri)	29–58
Merino (according to Jeppe[6])	64–88
Merino yearling. Skin from the shoulder	54
Merino ram. Newly born. Skin from front leg below knee	53
Coarse black lamb. Leicester crossbred. Skin from dock	35
Coarse sheep skin. Tanned and dyed foot robe	8

It is interesting to note that Nathusius at this time brought up the question of the exceedingly small ratio between fibre cross sectional area and the skin area on which the fibres grew. However, he thought that interspaces were quite necessary in order that the fibres might be properly nourished and have room to grow without too much physical pressure from their neighbouring fibres.

Cutting[7] made several reports on fineness measurements of Vermont Merinos and also reported on the number of fibres per square inch of skin surface on a sample cut from the freshly butchered pelt of a sterile Merino ram. He counted 276,480 pores and 222,300 fibres on the skin sample submitted to him. His counts do not agree with those of the present time, as the majority of workers have figures from 30,000 to 60,000 fibres per square inch for Merino sheep.

Spoettel and Taenzer[8] give attention to fleece density in one section of their paper on Racial Analytical Investigations of the Sheep in Regard to Skin and Hair. In their work they used parallel vertical skin sections instead of counting the fibres per unit skin surface, as had been done previously. They give the following table of fleece density or number of fibres per square millimetre of skin, counted on vertical skin sections.

Breed.	Maximum.	Minimum.	Average.
Somali	—	—	62
Oxford	50	30	—
Heidschnucke	45	34	—
Pommeranian	43	30	—
Bentheimer Native Sheep	41	32	—
Leine	40	23	—
Franken	39	31	—
Skudde	—	—	40
Geist	—	—	39
East Friesian Milk Sheep	—	—	36
Shropshire	—	—	35
Butjadinger	37	35	—
Karakule	37	33	—
Zackel	33	27	—
Merino	115	62	90
Moufflon	113	—	—
Wuerttemberg	100	60	—
Hampshire	90	—	—

Considerable variation was found in the different breeds, and no classification could be made of the breeds because of the variation of fleece density in which certain breeds overlapped other breeds.

Burns[9] gives the following data on the number of fibres per square inch of skin: Hampshires, 8,000 to 25,000; Rambouillets, 17,000 to 56,000; and Hampshire × Rambouillet crossbreds, 12,000 to 34,000. Assuming that the sheep has a skin area of 12 square feet and that the fibres grow fairly uniformly thick on the skin on different portions of the body, one can calculate the total number of fibres grown on the sheep. The Hampshires grew from 16,000,000 to 43,000,000 fibres, the Rambouillets 29,000,000 to 97,000,000, and the Hampshire × Rambouillet crossbreds, 21,000,000 to 59,000,000. There can be little doubt that there is a considerable drain on the body of a sheep when nourishing from 16,000,000 to 97,000,000 fibres all growing uniformly at the rate of about half an inch per month.

Taenzer[10] made an attempt to determine whether, in the Karakule, the number of groups which may be expressed by the density of the supporting hairs increases in proportion to the increase of the skin surface. He used the formula developed by Frank for determining the skin surface from the body weight. This formula consists of extracting the cubic root of the animal's weight in kilograms and squaring the resulting number, which gives a figure representing ten times the skin surface in square metres. His results showed that the assumption that hair density is proportional to body surface is not warranted and no definite relationship between body surface and hair density can be established.

Burns[11] reported a comparison of Australian Merino rams and American Rambouillet rams in which the following fleece densities were obtained:

Breed and Sex.	Number of Fibres per square inch of skin surface.	
	Shoulder	Thigh
Two Australian Merino Rams	61,000	51,000
Four American Rambouillet Rams ...	33,000	26,000

The Australian Merino rams were much superior in fleece density to the American Rambouillets.

Hawkesworth,[12] on page 484 of his book, states that Australian Merino stud flocks have on the average 45,000 fibres per square inch and may reach a maximum of 60,000.

Duerden[13] described a fleece caliper for separating the fibres from a definite skin area and made comparisons of weights and counts of numbers of fibres in the samples. He found a direct relationship between the scoured dry weight of a sample from a square inch of skin and the calculated number of fibres in samples taken from the shoulder, side, thigh, and belly areas of a Merino sheep.

Schandl[14] made a study of the extent of covering of Hungarian fine wool Merinos and their fleece fineness and density. He found in 60 Merinos that there was no relation between the amount of wool covering and the density of fibres and concludes that the practice of considering a high degree of wool covering as closely associated with fleece density and fineness is misleading.

Bosman and Mare[15] point out the importance of fleece density in stud ram breeding to produce quantity as well as quality of fleece. They found that the clean fleece weight is not necessarily proportional to the weight of clean wool produced per unit skin area, but also depends upon such factors as uniformity of density between different body areas, size of body, and the degree of skin wrinkling. They also point out that two fleeces with the same number of fibres per unit skin area but with different fibre thicknesses would show different degrees of compactness. They also found that much of the apparent density of the fleece when grasped with the hand is due more to the amount of yolk and springiness (resiliency) of the wool than to a thicker stand of fibres on the skin. They give figures to show that 92 per cent. of the skin area in Merino sheep does not produce either wool follicles or sweat and yolk glands. They found that a smooth-bodied ram produced more clean wool than a wrinkly type, which confirms the result obtained with Rambouillet sheep by Spencer, Hardy, and Brandon[16].

Spencer, Hardy and Brandon also found that clean fleece weight in Rambouillet sheep increases with an increase in density of fleece.

Bosman and Mare[16] point out further that there may be a possibility of the Merino sheep producing wool fibres on more than 8 per cent. of its total skin surface. They give the number of fibres per square inch on South African Merinos as from 29,500 to 52,500, which would mean that a sheep with an assumed skin area of 12 square feet would be growing from 60,000,000 to 90,000,000 wool fibres at a uniform rate of around half an inch per month.

Bosman[17] found, in expressing fleece density, that the weight-volume method gives results which agree closely with those obtained with the counting-weighing method and prefers the former method when a large number of routine samples are to be analysed. He found fleece densities of from 35,000 to 60,000 fibres per square inch of skin surface in samples taken from South African Merinos.

Bosman[18] gives further information on fleece density in the Merino sheep. He reports from 38,000 to 66,000 fibres per square inch of skin surface in the shoulder region from 10 South African Merino stud ewes. The percentage of skin area occupied by wool fibre ranged from 1·54 to 3·56 in these same ewes.

Hardy[19] reports on what might be designated the " swath " method of determining fleece density. In this method a swath of wool is clipped from the side of the sheep with a pair of hair clippers, the comb of which measures exactly one inch in width. The swath may be any length, but a length of four to five inches is recommended. After the wool is removed, the exact length of the swath is measured, the wool is thoroughly cleaned, dried, dusted and weighed, and the number of grams of clean wool per square inch is computed. Hardy mentions that this method may also have some application in the determination of commercial shrinkages.

Fraser and Nichols[20] use tattooed areas on the skin from which to obtain samples to express compactness of fleece through follicular activity, using the triangular method reported by Burns and Miller.[1] They think that a change in ration may possibly affect the fleece weight by producing more fibres, but this increase is, for the most part, due to an increase in fibre thickness and length.

Burns[21] reports on the use of electric tattooing needles to mark areas on the skin in obtaining wool samples from identical skin areas.

Wildman[22] surveys the field of fleece analysis and gives fleece analyses from two sheep, a Cheviot ewe and a Suffolk ewe. He took samples from nine body areas: point of shoulder, post scapula, anterior back, posterior back, side, hip, stifle, pin bone, and hind britch. The samples were taken with the Wyedesa Fleece Caliper described by Burns and Miller,[1] and fleece density was determined in the number of fibres per square centimetre of skin surface. The variation within areas was very large, and the differences between areas were covered up with the large variability within areas. However, the point of shoulder area was more dense in number of wool fibres per square centimetre than any other body area.

A recent publication by Bell, Spencer, and Hardy[23] reports that a comparison of visual fleece density or closure of fleece is grossly inaccurate as compared with an actual fleece density determination of the number of fibres per square inch of skin. The method developed by Hardy [19] was used

in these determinations. Thus the impression of extreme compactness of fleece obtained when grasping the fleece of American Merinos was due not to the number of fibres per unit skin area but to grease and dirt in the wool, while the Tasmanian Merinos with a softer, lighter feeling fleece had many more fibres per unit skin area. They report a marked decrease in fleece density at seven years of age, as compared with two, three, or four years of age, which were about the same. The Tasmanian Merinos had almost twice as many fibres per square inch of body surface as the American Merinos (16,000 to 24,000 for the American Merinos and 27,000 to 40,000 for the Tasmanian Merinos).

EARLY FLEECE DENSITY DETERMINATIONS AT WYOMING

In 1921 a crossbreeding experiment was started at Wyoming which has been reported by Burns.[24] During the course of this experiment several supplementary tests were made of fleece density.

The first instrument which was used was a pair of altered engineer's calipers described by Burns.[25] Duplicate samples were taken from skin areas one-half inch square, from the right shoulder area on five different breeds of sheep, so that all the different types of wools were represented.

Accuracy of Sampling for Fleece Density
Altered Engineer's Calipers

Breed.	Age	Sex	Ear tag No.	Calculated fleece density. Number of fibres per half-inch square of skin area		
				Sample 1	Sample 2	Difference
Rambouillet ...	3	ewe	432	4,777	4,677	100
Rambouillet ...	4	ewe	281	3,527	3,587	60
Rambouillet ...	4	ewe	255	3,454	5,009	1,555
Rambouillet ...	1	ewe	606	5,972	7,214	1,242
Rambouillet ...	lamb	ram	754	2,690	3,017	327
	Average difference for the Rambouillets ... 657					
Corriedale ...	2	ewe	2,139	2,719	3,027	308
Corriedale ...	2	ewe	465	3,584	2,640	924
Corriedale ...	2	ewe	2,091	5,515	5,143	372
	Average difference for the Corriedales ... 535					
Hampshire ...	3	ewe	351	2,650	2,796	146
Hampshire ...	3	ewe	325	2,641	2,684	43
Hampshire ...	5	ewe	87,950	2,123	1,754	369
Hampshire ...	1	ewe	614	2,278	2,776	498
Hampshire ...	lamb	ram	714	2,021	1,900	121
	Average difference for the Hampshires ... 235					
Oxford	4	ewe	230	1,857	2,065	208
Oxford	4	ewe	277	2,081	2,140	59
Oxford	3	ewe	335	1,655	1,881	226
	Average difference for the Oxfords ... 164					
Lincoln ...	1	ewe	631	1,545	2,350	805
Lincoln ...	lamb	ram	752	3,714	3,124	590
	Average difference for the Lincolns ... 698					
	Average difference for all 18 sheep ... 442					

The difference in calculated fleece density (number of fibres) was highest in the Lincolns and lowest in the Oxfords, and the average difference for all 18 sheep was 442 fibres. Using the variance method of Fisher[26] we find a standard deviation between these different fleece density figures of 426 fibres. In this method of calculation all factors influencing variation in

fleece density, such as sample trend and animal difference, were removed, leaving only the residual error due primarily to sampling. Thus the difference in fleece density due to the error of sampling could vary by 426 fibres. However, this figure includes not only the error of sampling, but also the error of determination in calculating the fleece density by the proportionate weight of 100 fibres as compared to the entire sample.

It is interesting to compare some earlier data on the sampling errors of the engineer's calipers as compared to the parallel-legged dividers. Both instruments separated the wool from a skin area measuring one-half inch square, and the calculated number of fibres was computed for duplicate samples.

The results indicated that the engineer's calipers were much more accurate in taking samples than the parallel-legged dividers, as the average difference between duplicate samples was only 35 in the former and 360 in the latter.

How many Sets of 100 Fibres should be used as a Basis for Calculating Fleece Density by Proportionate Weights ?

As a method of counting all the fibres per unit area is too tedious and impracticable, a system of proportionate weights was devised in which the weight of the 100 fibres measured to determine thickness was compared with the weight of the entire sample including the 100 fibres, and by a simple proportion the number of fibres in the sample can be calculated. This method encounters two difficulties: first, how many sets of 100 fibres should be used, and, second, is the weight method as accurate as an actual count ? The first question will be considered now, reserving the latter for a later section where the Wyedesa Fleece Caliper is discussed.

Five sets of 100 fibres were counted from each of a series of four samples to test out the effect of using one or more sets of 100 fibres as a basis for calculating fleece density by proportionate weights.

	Number of Fibres per One-Half Inch Square of Skin Surface. 100-Fibre Bundles used as a Basis for Calculation.					
Bundles	First 100	Second 100	Third 100	Fourth 100	Fifth 100	All 5
Sample No. 1 ...	4,777	5,415	5,296	5,244	5,360	5,218
Sample No. 2 ...	4,677	5,280	4,776	5,079	4,842	4,931
Sample No. 3 ...	6,119	6,267	6,630	6,332	6,940	6,458
Sample No. 4 ...	2,719	2,796	2,728	2,956	2,926	2,825

It is interesting to study the cumulative effect of taking more sets of 100 fibres in calculating fleece density. If the data given above are arranged in this manner, the following results are obtained.

	Number of 100-Fibre Bundles used in Calculation.				
	One	Two	Three	Four	Five
Sample No. 1	4,777	5,096	5,162	5,183	5,218
Sample No. 2	4,677	4,979	4,911	4,953	4,931
Sample No. 3	6,119	6,193	6,339	6,337	6,458
Sample No. 4	2,719	2,758	2,748	2,800	2,825

The variation as given by the calculation of the sums of squares gives a maximum of 293 in Sample No. 3 and a minimum of 99 in Sample No. 4. The figures for the other two samples are: 228 for Sample No. 1 and 219 for Sample No. 2.

Pelt *versus* Fleece Samples for Fleece Density Determination

In the crossbreeding test already referred to, some samples were taken from an F_2 wether just before he was butchered, and later samples were taken from the wet unstretched pelt.

	Fleece Density. Number of Fibres per square one-half inch of skin.	
	Fleece	Pelt
Shoulder	5,646	4,375
Throat	4,160	4,129
Side	4,708	3,174
Mid-back	2,639	6,664
Belly	4,788	3,115
Hip	4,191	3,044
Thigh	3,296	2,430
Dock	5,338	4,629
All body areas	4,346	3,945

There is a difference of 401 fibres between the fleece and pelt samples, a rather large difference in favour of the fleece samples. This is surprising, inasmuch as a pelt while yet wet is supposed to stretch, if any change takes place immediately after it is taken from the sheep's body. However, in this test the pelt samples with few exceptions were smaller in density than the fleece samples. This test showed conclusively, especially when compared with the results of Cutting[7] that it is very difficult to obtain accurate areas of skin from the pelt, upon which to base fleece density calculations.

THE WYEDENA FLEECE CALIPER

The Wyedena Fleece Caliper has been described by Burns and Miller[1] and since that time has been adopted and used by Bosman.[17] A study of the accuracy of sampling of the Wyedena Fleece Caliper, as shown by the variation between quadruplicate samples taken from the same body area has been worked out by the writer during his studies of fleece analysis at Edinburgh University. In this study samples of wool were available from 14 body areas from a Border Leicester and a Cheviot ewe.

Studies of Fleece Density
Table of Variance. Wyedena Fleece Caliper

Cheviot Ewe No. 117
Calculated Number of Fibres from a Skin Surface Measuring One-Half Inch Square

Body Area No.	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Total
1	2,351	2,206	2,401	2,592	9,550
2	2,461	2,119	1,970	1,820	8,370
3	1,750	2,139	1,784	2,215	7,888
4	1,963	1,720	2,047	2,082	7,812
5	1,851	1,499	2,060	2,137	7,547
6	1,651	2,134	1,420	1,798	7,003
7	1,418	1,725	1,802	1,923	6,868
8	1,567	1,531	1,771	1,424	6,293
9	1,435	1,293	1,529	1,782	6,039
10	1,365	1,345	1,799	1,539	6,048
11	1,727	1,604	1,424	1,734	6,489
12	1,517	1,204	1,629	1,242	5,592
13	1,276	1,098	1,119	1,050	4,543
14	1,117	1,083	1,210	992	4,402
Sum	23,449	22,700	23,965	24,330	94,444
Sum of Squares	41,199,939	38,892,660	42,634,131	44,977,020	663,719,642

Fig. 1.
Border Leicester Ram with body areas marked from which samples were taken for testing the Wyedina Fleece Caliper.

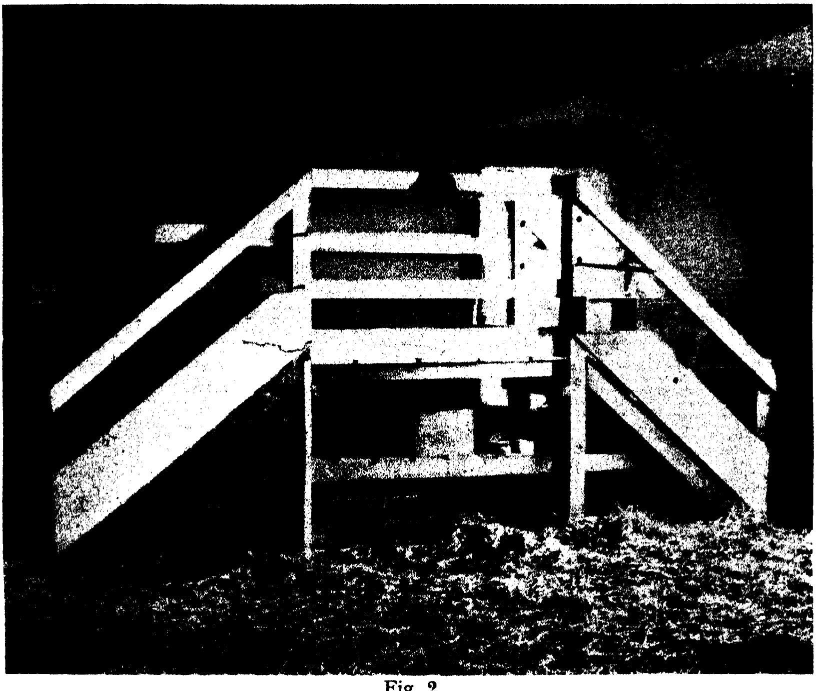


Fig. 2.
Wool Sampling Crate for Sheep. Wyoming Agricultural Experiment Station.

Variation due to	Degrees of freedom	Standard deviation	Mean variance	Gross variance
All causes	55	391	153,163	8,423,944
Sample trend ...	3	51	35,677	107,032
Balance...	52	400	159,941	8,316,912
Area difference ...	13	358	511,547	6,650,105
Remainder	39	207	42,739	1,666,807

Error of sampling for density (Wyedena Fleece Caliper) : 207 fibres.

In the Cheviot fleece the variation due to all causes was 391 fibres, while the sample trend was only 51 fibres. The area difference, 358 fibres, was larger, leaving a balance of 207 fibres due to residual errors of determination, such as the selection of a prescribed area of skin on the sheep and calculating the number of fibres in the sample by means of proportional weights.

Studies of Fleece Density
Table of Variance. Wyedena Fleece Caliper

Border Leicester Ewe No. K953

Calculated Number of Fibres from a Skin Surface Measuring One-Half Inch Square

Body Area No.	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Total
1	2,515	1,969	1,614	2,755	8,853
2	2,083	2,513	1,297	1,578	7,471
3	2,115	1,690	2,248	2,074	8,127
4	2,191	2,026	2,665	1,758	8,640
5	1,952	1,612	2,058	1,977	7,599
6	1,914	1,698	1,757	1,819	7,188
7	1,763	1,877	1,464	1,813	6,917
8	1,974	1,895	1,669	1,811	7,349
9	1,714	1,765	2,051	1,782	7,312
10	2,649	1,942	1,650	1,820	8,061
11	2,400	1,949	2,043	2,388	8,780
12	2,092	2,162	2,249	1,986	8,489
13	2,132	1,077	1,467	1,628	6,304
14	1,439	1,144	1,489	1,491	5,563
Sum	28,933	25,319	25,721	26,680	106,653
Sum of squares	61,123,971	47,576,907	49,224,365	52,264,258	825,172,205

Variation due to	Degrees of freedom	Standard deviation	Mean variance	Gross variance
All causes	55	359	128,490	7,066,958
Sample trend ...	3	126	186,831	560,492
Balance	52	354	125,124	6,506,466
Area difference ...	13	247	243,885	3,170,508
Remainder	39	292	85,537	3,335,958

Error of sampling for density (Wyedena Fleece Caliper) : 292 fibres.

In the Border Leicester fleece the sample trend was much larger than in the Cheviot, while the area difference was slightly less. This indicates that there was a tendency for the Cheviot fleece to be more variable in density from area to area. The variation between samples within the area was larger in the Border Leicester fleece, due not so much to the inherent variability of density within the area, as to the difficulty encountered in obtaining an accurate density sample due to the entanglement of the wool staples in the

Border Leicester fleece. The variation due to all causes was 359 fibres, while the sample trend was 126 fibres. The area difference, 247 fibres, was larger, leaving a balance of 292 fibres due to residual errors of determination, such as the selection of a prescribed skin area on the sheep and calculating the number of fibres by means of proportional weights.

Studies in Fleece Density

Cheviot Ewe No. 117, and Border Leicester Ewe No. K953

Table of Variance

Variation due to	Degrees of freedom	Standard deviation	Mean variance	Gross variance
All causes	111	389	151,548	16,821,792
Sample trend ...	3	67	124,002	372,005
Balance	108	390	152,313	16,449,787
Area difference ...	27	321	413,019	11,151,503
Remainder	81	256	65,411	5,298,284

Error of sampling for density (Wyedena Fleece Caliper) : 256 fibres.

When the figures from both the Cheviot and Border Leicester fleeces are combined we find that the error of sampling for the Wyedena Fleece Caliper is 256 fibres, which is about half of the error found with the engineer's calipers (442 fibres). This shows that the Wyedena Fleece Caliper is almost twice as accurate as the engineer's calipers in defining the skin area from which the wool samples are clipped.

THE WYEDESA FLEECE CALIPER

As noted in a former publication,[1] an instrument with clamping jaws would be exceedingly desirable, for this would enable the operator to separate the wool sample from a definite skin area after the sample and contiguous wool had been clipped from the skin. The Wyedesa Fleece Caliper is a modification of the Wyedena Fleece Caliper in which the clamping jaw feature has been added. A recent mechanical improvement of the Wyedesa Fleece Caliper has been incorporated in an instrument designated as the Wira Caliper due to Wildman.[27]

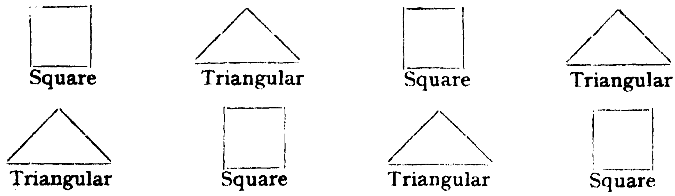
The Wool Department of the Wyoming Agricultural Experiment Station has just completed a test of the accuracy of sampling of the Wyedesa Fleece Caliper as indicated by the variability of the calculated and counted number of fibres per square centimetre of skin. Quadruplicate samples were taken from square and triangular shaped skin areas on the side area of five different breeds of sheep covering the major types of improved wools. The triangular shaped skin areas were used as a double-check on the square shaped skin areas sampled by the Wyedesa Fleece Caliper.

Animals Used

Three ewes were selected as representing the two extreme and the average wool type in each of five breeds : Lincoln, Corriedale, Hampshire, Southdown, and Rambouillet. These five breeds represent the main types of improved wool as found in the chief wool producing countries.

Method of Sampling

Inasmuch as a fairly large uniform skin area was needed, the side was selected as the location of the samples. Quadruplicate samples were taken from each shape of area as shown in the following diagram :



These samples were taken adjacent to each other so as to reduce the inherent variability in the fleece to a minimum. The technique of sampling is the same as outlined by Burns and Miller.[1] To facilitate the sampling of the animals without laying them on a table, which was done in earlier sampling, a sampling crate was designed, which is shown in Figure No. 2.

The dimensions of this crate can readily be determined by comparison with the yardstick leaning against the upright in the left foreground. The sheep to be sampled is caught and a leather halter is placed on its head; then it is led and pushed up the inclined floor at the left side of the crate and on to the floor of the crate. One of the side boards is shown slid back, and

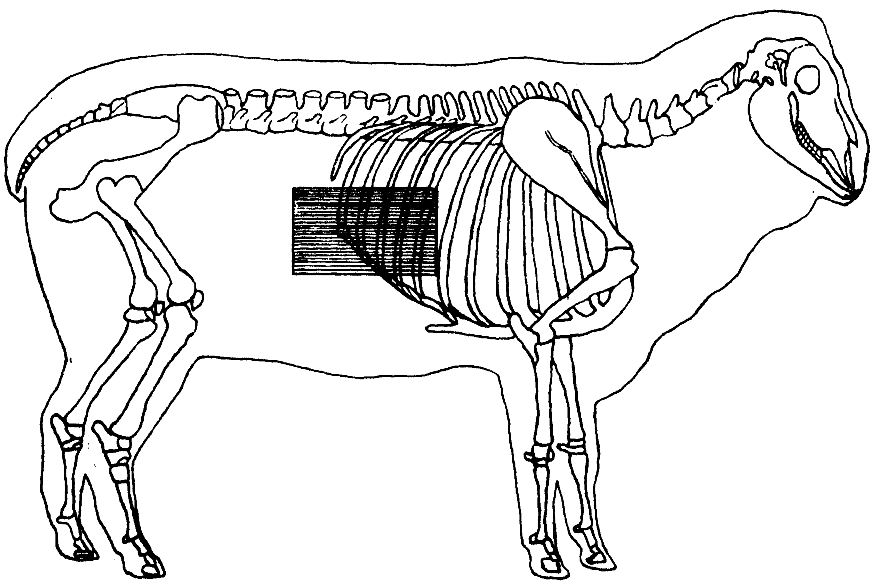


Fig. 3

Diagram of outline and skeleton of sheep showing location of side body area from which the wool samples were clipped.

when sampling both are slid back out of the way. The small piece of pipe shown protruding from the upright on the right side of the crate is slipped through the ring of the halter, and it is surprising how quiet the sheep will stand while being sampled. The upper holes are for larger sheep, while the lower ones take care of smaller ones. The light shade hanging on the top rail of the crate is used to reflect the light from a 300 watt globe used to illuminate the area being sampled, and the box at the right side holds the sample containers. The large box below holds the extra wool cleared from

the area to obtain the small samples. This crate is quite simple to construct and serves admirably for sampling, for the sheep stands in a natural position and the height of the crate makes it very easy for the operator to work. The inclines may be made more gradual if room permits.

All the samples taken with the Wyedesa Fleece Caliper were from square skin areas with surface of one square centimetre. The triangular-shaped skin areas, from which the wool samples were clipped, had the following areas in the different animals:

Three Lincolns...	1·28 square centimetres
Three Corriedales	1·10 ,, ,,
Three Hampshires	1·00 ,, ,,
Three Southdowns	0·78 ,, ,,
Three Rambouillets	0·82 ,, ,,

The side area was located by taking the end of the last solidly attached rib as the centre of the area. This point is shown in Figure No. 3.

Method of Preparing the Samples for Measurement

The samples were thoroughly washed in hot soap solution (12 ounces of textile soda and 8 ounces of soap flakes made up to 10 gallons of solution) at 130° F., so that all grease and wax was removed, and then rinsed in warm water at 110° F. The samples were placed in folding containers of galvanised wire gauze (16 mesh to inch) which held the samples so that the staple formation was not greatly disturbed during the washing process. Composite samples were then prepared for each of the 120 samples (60 from square- and 60 from triangular-shaped skin areas) by repeated splitting of the sample until 16 zones had been prepared. A small wisp of fibres from the side of each of these zones was taken out, and these 16 wisps made up the composite sample.

Measurement Technique

One hundred fibres were measured for thickness by means of the micrometer caliper and were laid aside. They were washed along with the remainder of the sample, and then were weighed after conditioning for two days. In order that all the fibres might be subjected to the same conditions of moisture during the weighing process, the remainder of the sample and the 100-fibre bundle were placed together in the weighing bottle and weighed, then the 100-fibre bundle was removed and another weight was recorded. The weighing bottle was tared before each series of weights, and from these weights the weight of the entire sample including the 100-fibre bundle as well as the weight of the latter was calculated. From these weights the number of fibres in the sample was calculated by a simple proportion.

If we assign the following legend, it will be much easier to follow through the calculation of the number of fibres in a sample by proportionate weights.

W_t = total weight.

W_{100} = weight of 100 fibres.

N = number of fibres in entire sample.

$$W_t : W_{100} = N : 100.$$

Solving this equation $N = 100\, W_t \div W_{100}$.

One hundred fibres are usually used in this method, but if by mistake a larger or smaller number of fibres is used in the partial sample, this number can be substituted for the 100 in the upper part of the equation.

The Variability of Fleece Density in Samples taken from Square and Triangular-Shaped Skin Areas

A Test of the Wyedesa Fleece Caliper

Fleece Density Expressed as the Number of Fibres per Square Centimetre of Skin Surface

Mean Density and Probable Error of the Mean

	Samples from a square skin area (Wyedesa Fleece Caliper)	Samples from a triangular skin area
Three Lincolns	912 ± 38	1,033 ± 22
Three Corriedales	1,560 ± 60	2,125 ± 122
Three Hampshires	965 ± 31	1,239 ± 29
Three Southdowns	1,375 ± 41	2,116 ± 101
Three Rambouillets	3,202 ± 100	4,200 ± 141
All breeds (15 animals) ...	1,603 ± 77	2,143 ± 108

In all cases the triangular areas gave samples with more fibres per square centimetre than the square areas. This points to the possibility that there is better definition of the margin of the area in the square shaped areas. On the average there is considerably less variation between the quadruplicate samples from the square areas than from the triangular areas.

Studies of Fleece Density

Table of Variance

Square Skin Areas Sampled with the Wyedesa Fleece Caliper

Calculated Number of Fibres from a Skin Surface Measuring One Centimetre Square

Sheep All ewes	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Total
Lincoln No. 049	948	786	784	751	3,269
Lincoln No. 804	1,318	637	1,128	1,092	4,175
Lincoln No. 942	977	681	829	1,016	3,503
Corriedale No. 701	1,426	1,745	1,436	2,024	6,631
Corriedale No. 811	1,545	1,190	1,120	1,501	5,536
Corriedale No. 918	1,602	1,387	1,502	2,246	6,737
Hampshire No. 016... ...	1,078	1,004	771	1,007	3,860
Hampshire No. 708... ...	1,253	1,167	757	935	4,112
Hampshire No. 801... ...	824	818	1,131	837	3,610
Southdown No. 034 ...	1,203	1,457	1,541	1,661	5,862
Southdown No. 039 ...	1,209	1,400	1,677	1,541	5,827
Southdown No. 964 ...	1,457	1,111	985	1,256	4,809
Rambouillet No. 007 ...	3,386	3,371	3,141	3,986	13,884
Rambouillet No. 746 ...	3,695	3,651	3,414	3,141	10,644
Sums	23,905	22,952	23,176	26,417	96,450
Sums of Squares	48,074,347	47,409,070	47,033,544	60,964,601	801,806,612

Variation due to	Degrees of freedom	Standard deviation	Mean variance	Gross variance
All causes	59	906	820,986	48,438,187
Sample trend ...	3	106	168,390	505,171
Balance	56	925	855,947	47,933,016
Animal difference ...	14	900	3,243,448	45,408,278
Remainder	42	245	60,113	2,524,738

Error of sampling for fleece density (Wyedesa Fleece Caliper) : 245 fibres

Studies of Fleece Density

Table of Variance

Triangular Skin Areas Sampled with Steel Pins

Calculated Number of Fibres from a Skin Surface Measuring One Centimetre Square

Sheep. All ewes	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Total
Lincoln No. 049 ...	1,207	1,103	1,093	1,025	4,428
Lincoln No. 804 ...	799	928	1,192	924	3,843
Lincoln No. 942 ...	1,118	976	1,046	986	4,126
Corriedale No. 701 ...	2,028	2,097	1,763	2,460	8,348
Corriedale No. 811 ...	1,338	1,609	1,672	1,476	6,095
Corriedale No. 918 ...	2,979	2,787	3,038	3,111	11,915
Hampshire No. 016 ...	1,560	1,075	1,202	1,338	5,175
Hampshire No. 708 ...	1,242	1,204	1,251	1,178	4,875
Hampshire No. 801 ...	1,114	968	1,369	1,370	4,821
Southdown No. 034 ...	2,236	2,520	1,451	1,974	8,181
Southdown No. 039 ...	2,882	2,665	2,008	2,890	10,445
Southdown No. 964 ...	1,228	1,903	1,591	2,044	6,766
Rambouillet No. 007 ...	4,190	5,132	4,403	4,161	17,886
Rambouillet No. 746 ...	5,941	3,719	4,364	4,080	18,104
Rambouillet No. 809 ...	3,280	4,170	3,127	3,829	14,406
Sums	33,142	32,856	30,570	32,846	129,414
Sums of squares ...	101,763,388	95,957,612	80,604,572	90,888,196	1,450,995,544

Variation due to	Degrees of freedom	Standard deviation	Mean variance	Gross variance
All causes	59	1,236	1,526,792	90,080,711
Sample trend ...	3	80	95,504	286,611
Balance	56	1,266	1,603,468	89,974,200
Animal difference ...	14	1,222	5,972,559	83,615,829
Remainder	42	384	147,104	6,178,371

Error of sampling for fleece density (Triangular Method of Sampling) : 384 fibres

The remainder of the variation between samples gives figures of 245 for the square samples and 384 for the triangular ones. The method of sampling the square areas would tend to give less chance for variation than the method using triangular ones, which requires a much more careful parting of the wool on the margins of the area, as well as a careful measurement of the edges of the area. The Wyedesa Fleece Caliper, on the contrary, has proved in practice what seemed quite logical in theory, namely, that this instrument is much more positive and accurate in delineation of a definite skin area than any method of manual separation of wool on the skin. Both these methods of sampling are much more accurate than previous methods using calipers and dividers, which gave higher variations between the replicate samples.

The wool samples from a square and a triangular skin area from one sheep from each of the five different breeds were used for a study of the calculated density as compared with the actual count. Each 100-fibre bundle was kept separate, and some very interesting results were obtained, which are shown in Table III.

Table III

A Comparison of Calculated Fleece Density in Number of Fibres with an Actual Count

Sample	Counted density (No. fibres in sample)	Calculated Density			
		Original 1st 100 fibres	Mean of all 100s as counted out	Mean 1st 3 sets of 100	Mean 1st 5 sets of 100
Lincoln No. 049 Square No. 4 ...	826	751	829	733	800
Lincoln No. 942 Triangular No. 2 ...	1,550	1,167	1,559	1,323	1,444
Corriedale No. 918, Square No. 2 ...	1,435	1,387	1,435	1,297	1,382
Corriedale No. 811, Triangular No. 1 ...	1,742	1,628	1,749	1,718	1,684
Hampshire No. 016, Square No. 3 ...	964	771	951	766	842
Hampshire No. 708, Triangular No. 4 ...	1,044	866	1,102	817	861
Southdown No. 034, Square No. 1 ...	1,441	1,203	1,459	1,263	1,292
Southdown No. 964, Triangular No. 1 ...	1,818	1,607	1,851	1,510	1,612
Rambouillet No. 746, Square No. 4 ...	2,994	3,141	3,004	2,903	2,831
Rambouillet No. 007, Triangular No. 4 ...	2,803	2,617	2,859	2,507	2,696
Averages for all breeds :					
Square samples	1,532	1,451	1,536	1,400	1,429
Triangular samples ...	1,791	1,577	1,824	1,575	1,659
All samples	1,662	1,514	1,680	1,488	1,544

The calculated density based on the weight of all sets of 100-fibres and the actual count agree quite closely, and this agreement shows that there is a close agreement between the fibre weight and the number of fibres. The error involved in the calculation of fleece density is then largely due to the selection of the 100 fibres which are weighed. There is little advantage in weighing three or five sets of 100 fibres in calculating density as compared to the use of the first set of 100 fibres, provided the composite sample from which these 100 fibres are taken has been repeatedly "quartered" into 16 zones before making up the composite sample. In other words, the calculated density taken from a 100-fibre group is just as representative of the sample from which it was taken as is a sub-sample made up from a number of 100-fibre groups.

The main object of this paper has been to present the second portion of the work on fleece density. The first portion dealt with the various instruments and methods used in obtaining samples for the determination of fleece density. This, the second portion, deals with the accuracy of the Wyedesa Fleece Caliper as an instrument for the determination of fleece density, as well as a comparison with the triangular sampling method. The many ramifications of the problem of fleece density will of necessity be left for later papers after an enormous amount of work has been finished dealing with this interesting and most valuable of the dimensional fleece characters.

SUMMARY

The accuracy of the Wyedesa Fleece Caliper, as indicated by the variation between quadruplicate samples and by a comparison with contiguous quadruplicate samples, is reported.

The literature on fleece density determination is summarised.

The accuracy of engineer's calipers and the Wyedena Fleece Cali per, as shown by the variation of replicate samples, is reported.

REFERENCES

[1] Burns, R. H., and Miller, W. C. *J. Text. Inst.*, 1931, **22**, T547-T564.
[2] Hultz, F. S. *Wyoming Agric. Expt. Stat. Bull.*, 1927, No. 154, p. 110.
[3] Hultz, F. S., and Paschal, L. J. *Wyoming Agric. Expt. Stat. Bull.*, 1930, No. 174, p. 21.
[4] Nathusius, W. V. "Das Wollhaar des Schafs in histologischer und technischer Beziehung mit vergleichener Beruechsichtigung anderer Haare und der Haut." Berlin : Verlag Wiegandt und Hempel, 1866.
[5] Petri, B. "Das Ganze der Schafzucht." Erster Theil. Wien. Carl Schaumburg und Comp. 1825.
[6] Jappe. Results given to meeting of agriculturists at Munich in 1844. See C. L. Fleischmann, "Account of Trip to Germany," Patent Office Report, Washington, 1847.
[7] Cutting, Dr. *Register of the Vermont Merino Sheep Breeders' Assn.*, 1883, II, 102-105.
[8] Spoettel, W., and Taenzer, E. Abdruck aus dem "Archiv. fuer Naturgeschichte" 89 Jahrgang, Abteilung A, Heft 6, Seite 167-172. Berlin : Verlags-Buchhandlung R. Stricker, Nicolaische, 1923.
[9] Burns, R. H. *Wool Record,* 1926, **30**, p. 555.
[10] Taenzer, E. *Kuehn Archiv.*, 1928, **17**, 151-301.
[11] Burns, R. H. *National Wool Grower*, 1928, XVIII, **12**, 34.
[12] Hawkesworth, A. "Australasian Sheep and Wool." Sixth Edition, Sydney, 1930.
[13] Duerden, J. E. *Union of South Africa. Dept. of Agriculture.* Pan-African Agricultural and Veterinary Conference Papers : Agricultural Section, 1929, pp. 355-358.
[14] Schandl, J. Correlation of the Extent of Wool Covering of Fine Wool Merinos and Fineness of Wool and Density of Fleeces. 1930. (Translated Title.) Original in Hungarian. *Biological Abstracts*, 1932, **6**, 4770.
[15] Bosman, V., and Mare, G. S. *Farmer's Weekly*, 1933, pp. 194, 195.
[16] Spencer, D. A., Hardy, J. I., and Brandon, Mary J. *U.S. Dept. of Agric. Technical Bull.*, 1928, No. 85.
[17] Bosman, V. *Onderstepoort J. of Vet. Science and Animal Industry*, 1934, **3**, No. 1, pp. 217-221.
[18] Bosman, V. *Farming in South Africa*, 1934, **9**, p. 100.
[19] Hardy, J. I. *The Sheepman*, 1933, **4**, pp. 8, 9.
[20] Fraser, A. H. H., and Nichols, J. E. *The Empire Journal of Expmntl. Agric.*, 1934, II, **5**, pp. 9-19.
[21] Burns, R. H. *Proc. of Amer. Soc. of Animal Production*, 1935, pp. 146-151.
[22] Wildman, A. B. *J. Text. Inst.*, 1936, **27**, P181-P196.
[23] Bell, D. S., Spencer, D. A., and Hardy, J. I. *Ohio Agric. Expt. Station Bulletin*, 1936, No. 571.
[24] Burns, R. H. *Wyoming Agric. Expt. Stat. Bull.*, 1933, No. 196.
[25] Burns, R. H. *Proc. of Amer. Soc. of Animal Production*, 1924, pp. 92-97.
[26] Fisher, R. A. "Statistical Methods for Research Workers." Edinburgh, 1928.
[27] Wildman, A. B. *J. Text. Inst.*, 1936, **27**, T177-T182.

Received 2/2/37

THE JOURNAL OF THE TEXTILE INSTITUTE

TRANSACTIONS

8—A REVIEW OF TESTING INSTRUMENTS AND AN IMPROVED RECORDING FIBRE TESTER

By GOHACHI OSUMI and ETSURO KATO

Textile Department, Tokyo Institute of Technology

INTRODUCTION

With the great development of the rayon industry, the examination of the single fibre has become an important factor in the determination of the properties of the material. Up to the present, however, although many types of apparatus have appeared, there is scarcely one which is perfectly satisfactory. The present authors have recently developed a new design in an attempt to meet the objections to existing machines. In this paper a brief description with comments on each known type of fibre testing apparatus is first given. A full account of the construction and operating characteristics of the instrument due to the present authors follows.

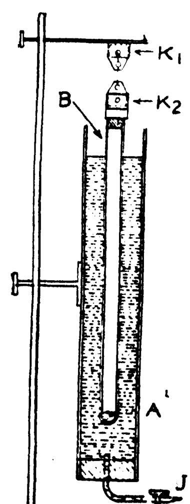


FIG. 1.

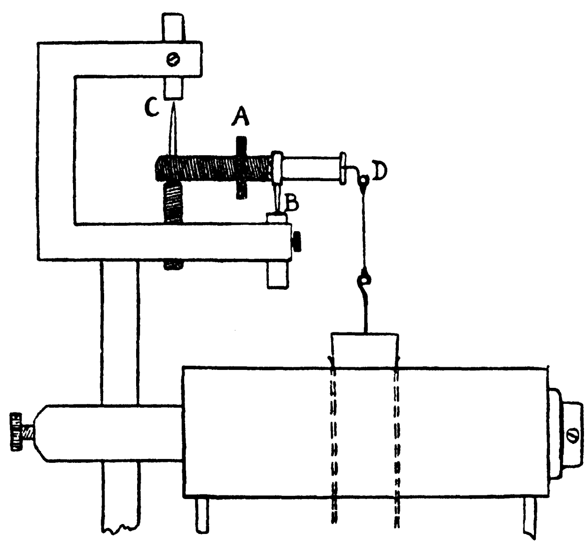


FIG. 2.

I. INSTRUMENTS FOR TESTING FIBRE STRENGTH

(a) Hydrostatic Type

The work on the hydrostatic type of fibre testing apparatus was originated by Charles O'Neill[1] and the experiment with his apparatus was first carried out in 1863. This apparatus shown diagrammatically in Fig. 1 has a tubular float *B* vertically held in a cylindrical vessel *A* filled with

water. The fibre to be tested is clamped to the float and to the fixed arm above it. By gradually draining the water through the outlet tube J at the bottom, the tension on the fibre may be steadily increased until the fibre breaks. The breaking load of the fibre may then be calculated from the difference between the initial and final levels of the water or the quantity of the water drained by the formula

$$F = \frac{V r^2}{R^2 - r^2}$$

where F stands for breaking load in grams, V for the water drained off in cubic centimetres, r for the radius of the float in centimetres, and R for the radius of vessel in centimetres, a small correction being neglected. This apparatus was later improved by Yves Henry and by Hughes.[2]

Fig. 2 illustrates an improved apparatus by Mann and Peirce,[3] the feature of which is the device for straightening the fibre mounted on it without developing a tension.

The authors feel rather sceptical regarding the accuracy of all instruments of the hydrostatic type. As they employ water, it seems very difficult if not impossible to carry out the test under the normal atmospheric conditions.* The effect of surface tension on the float and the possible delay in closing the draining tube when the fibre is broken are other possible sources of error.

(b) Balance Type

For testing fibres Bowman[4] employed the balance mechanism and measured the strength by sliding the weight over the lever. Matthews[5] also used a similar set-up. Fig. 3 illustrates a balance type tester which was designed by Mackenzie. The beam of the apparatus is initially balanced by means of the weight W so that the pointer indicates the zero reading on the scale S. A fibre is then clamped in the jaws J. By turning T, R is moved so that a tension is applied to the fibre. The distance through which R is traversed, which is proportional to the tension, is read on the scale G while the elongation of the fibre is indicated on the scale S. In this apparatus it is not an easy task to move R without causing a vibratory tension in the fibre which introduces an error in measuring the feeble tensile strength. In order to overcome the defects of this apparatus, Barratt[6] constructed the fibre balance which is illustrated in Fig. 4. From one end of the balance beam is suspended a steel rod, the greater part of which is inside a solenoid. The current through the solenoid is controlled by means of a rheostat and the load is read indirectly by an ammeter.

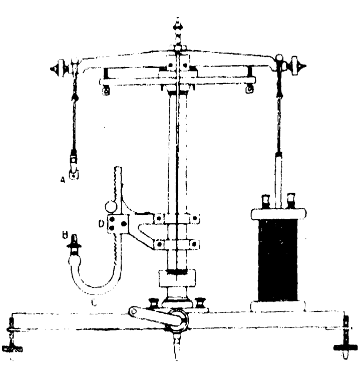


FIG. 4.

By means of an apparatus as shown in Fig. 5, Krais[7] deduced the strength of a fibre from the quantity of the water poured into the bucket which is suspended from one end of the beam. Fig. 20 illustrates an apparatus designed by Heim Richard,[8] in which there is a float suspended in the mercury and by gradual lowering of the mercury level a steadily increasing load may be applied to the test piece. However, with any of

*This difficulty is met in the paper by Mann and Peirce.[3]—EDITOR.

the apparatus aforenamed the problem of the friction between the lever and fulcrum remains.

(c) Pendulum Type

Fig. 6 illustrates a pendulum type of fibre tester. The tensile strength developed in this apparatus may be calculated by the formula—

$$T = \frac{PR \operatorname{Sin} \theta}{r}$$

The well-known yarn testing machines by Baer, Schopper, Goodbrand, Tänzer,[9] are all of this type. Fig. 7 shows the apparatus designed by Balls[10] to determine automatically the breaking load of each of 50 fibres in succession. The instrument illustrated in Fig. 9 is due to Tänzer. As with instruments of the balance type, testers employing the pendulum loading are also subject to error due to friction.

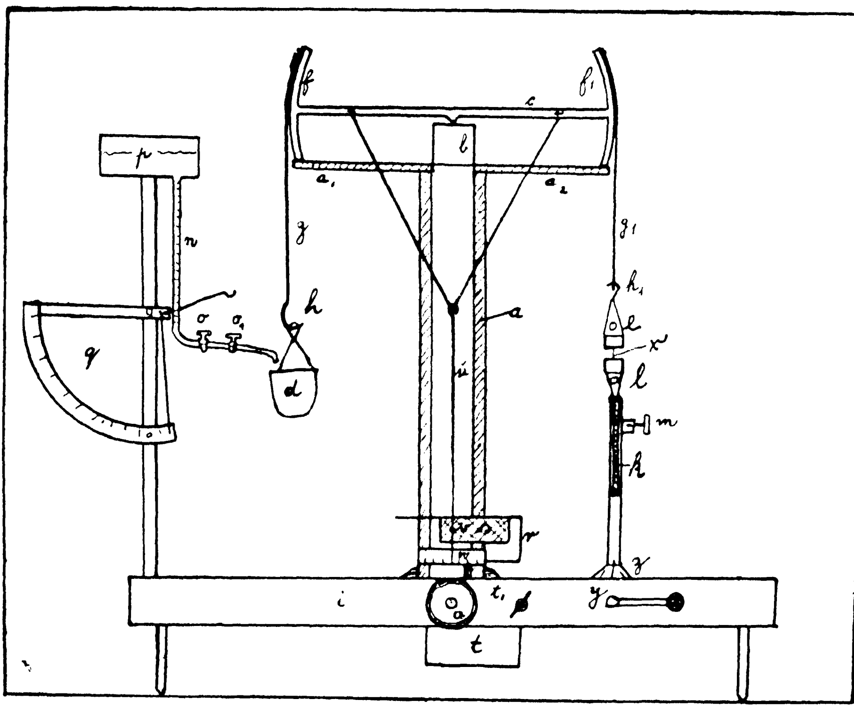


FIG. 5.

(d) Spring Type

In fibre testers of the spring type the spring is loaded through the fibre to be tested. As the load is equal to the tension in the fibre, the deflection of the spring and its calibration give the strength of the fibre immediately. In this type of apparatus the question of friction is, of course, entirely eliminated. The instruments by Shorter and Hall,[11] Polanyi,[12] Denham and Lonsdale,[13] Aoki and Atsuki,[14] and Cliff[15] are all of this type. The instrument invented by the authors, of which a full description is given below, also belongs to this group. Fig. 8 illustrates the apparatus of M. Polanyi, in which a specimen D is clamped in between the holders F_0 and F_n. The pull applied to D by lowering F_n by means of the screw of the micrometer V is

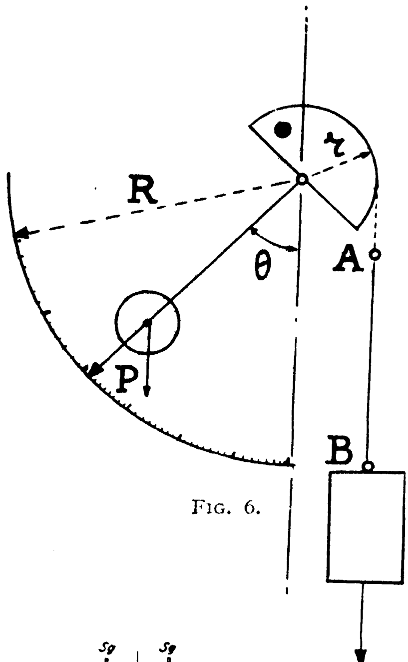


FIG. 6.

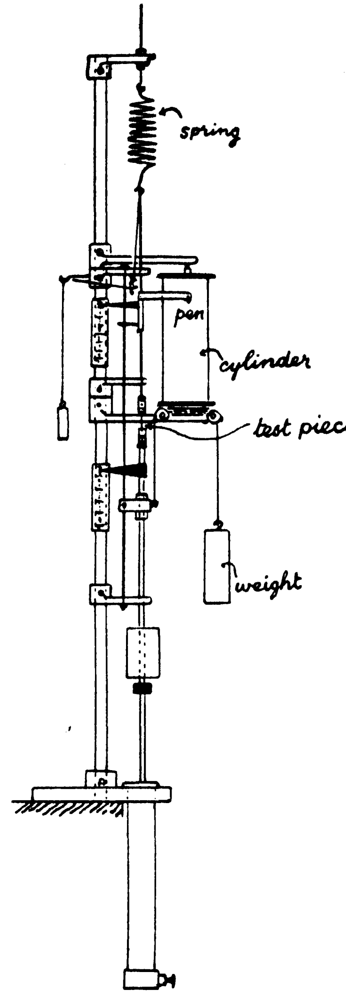


FIG. 10.

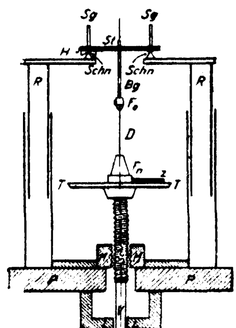


FIG. 8.

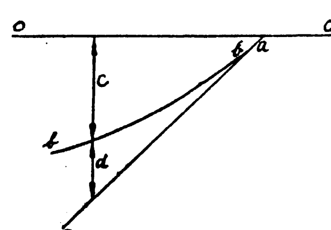


FIG. 11.

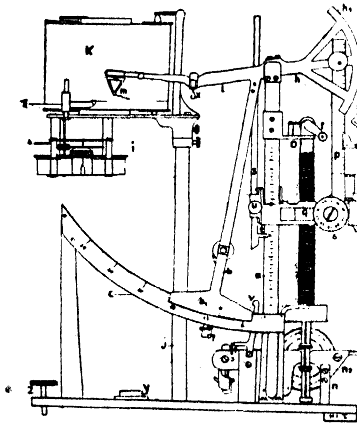


FIG. 9.

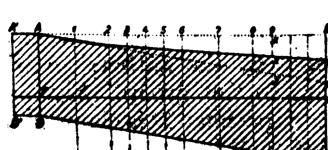


FIG. 12.

in turn transmitted to the spring S_t. The deflection of the spring is read through the mirrors S_g by the optical lever principle. The use of an optical lever in the test, however, is quite involved and the test requires considerable time as well as care. The instrument by Amsler shown in Fig. 10, and that by Aoki and Atsuki, are discussed below.

II. INSTRUMENTS FOR TESTING FIBRE STRENGTH AND ELONGATION

Apparatus for measuring the elongation in addition to the strength of fibres will now be considered. The instruments shown in Fig. 1 and Fig. 2 are used for measuring the strength only, while that of Mackenzie in Fig. 3 is capable of indicating the elongation on the scale S as already stated. However, on the scale S it would be almost impossible to read with the naked eye, say, 10 per cent. or 1 mm. of elongation in a test piece 10 mm. long. In the instrument shown in Fig. 8 the elongation is measured by means of the micrometer V, which at the same time applies the necessary pull. But the reading of the micrometer is correct only when the sag in the upper holder F_0 is negligibly small. In Fig. 4 and Fig. 5 the central pointers indicate the elongation. In order to magnify the reading it is necessary

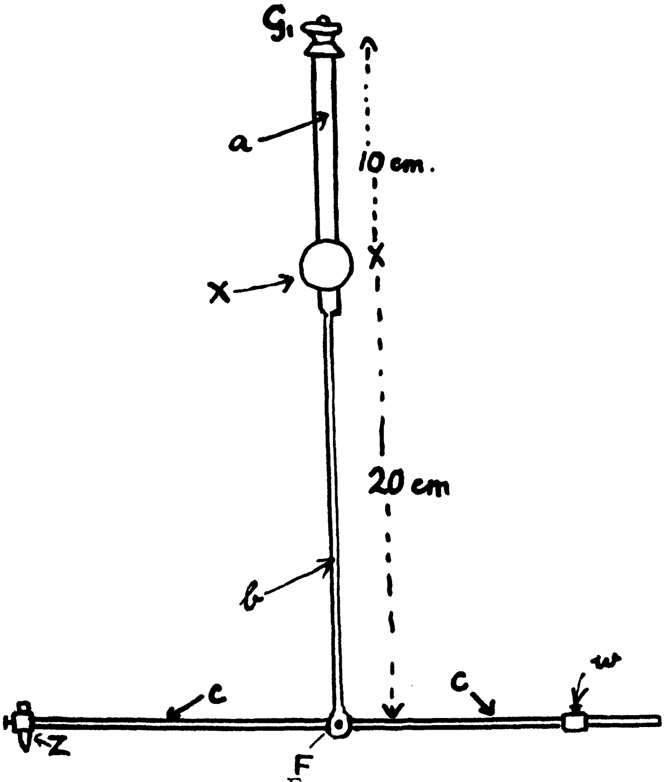


FIG. 14.

either to increase the length of the pointer or to shorten the arm of the lever. Lengthening the pointer increases the height of the set-up, and hence it is subject to more vibration. Shortening the arm, on the other hand, involves the sacrificing of sensitiveness. In fact it is difficult to magnify the reading in this type of set-up. This matter will be fully discussed below.

III. APPARATUS FOR RECORDING FIBRE STRENGTH AND ELONGATION

The construction of apparatus for automatically recording the strength and elongation of a fibre involves not only the question of suitable magnification of the tension and elongation, but also the tracing of the record and the elimination of the friction between the pen and paper. The most generally acceptable form of record employs rectangular co-ordinates.

The Krais type of instrument is capable of modification so that the load and the elongation of a fibre may be automatically recorded. In this

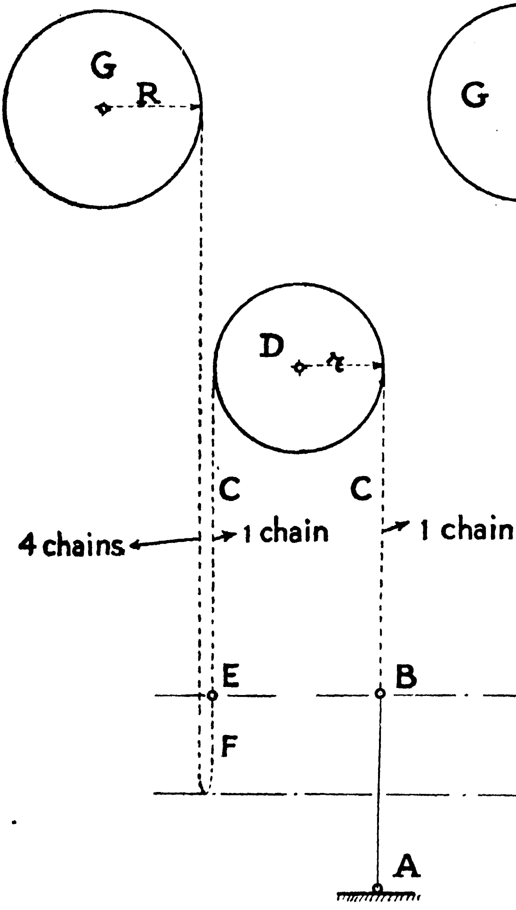


FIG. 15.

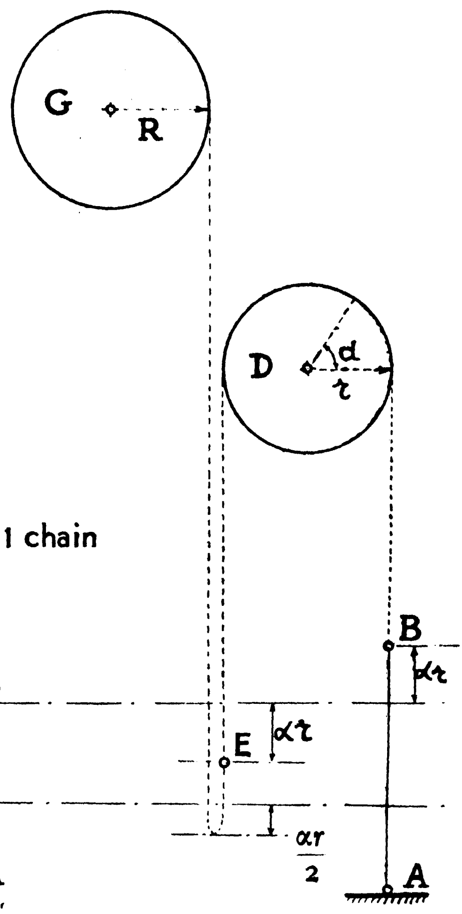


FIG. 16.

instrument the effect of friction in the recording mechanism cannot be overlooked. Also in the apparatus by Tänzer shown in Fig. 9 and in that by Amsler shown in Fig. 10 there is friction between the recording pen and paper.

In order to discuss the apparatus by Aoki and Atsuki, the set-up in Fig. 10 will first be examined. As the piston in the oil tube is lowered at a uniform speed, the force transmitted by the fibre stretches the spring so that its lower terminal moves downward. The pen which is carried on the lower end of the spring is so set that it touches lightly on the recording drum which is turned by the piston through a string connection. If the pen is

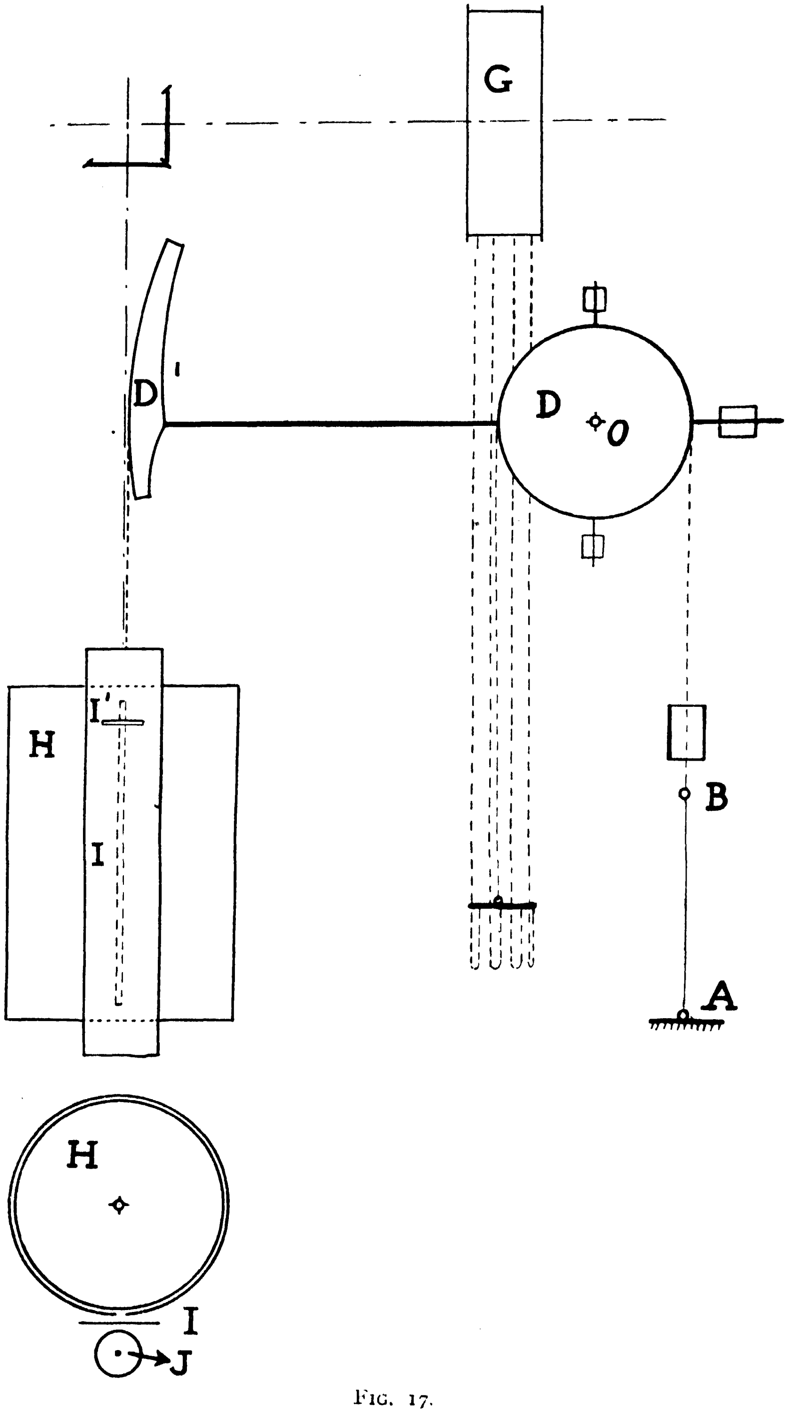


FIG. 17.

held stationary and the piston is lowered, a horizontal line such as *O-O* in Fig. 11 would be drawn on the drum. If the drum is held stationary and the pen is lowered, a vertical line would be drawn which represents the elongation of the spring, which is proportional to the tension. If there were no elongation in the fibre to be tested, the pen and the drum surface must travel equal distances at right angles and hence a straight line would be drawn at an angle of 45° to the horizontal in Fig. 13. In reality, however,

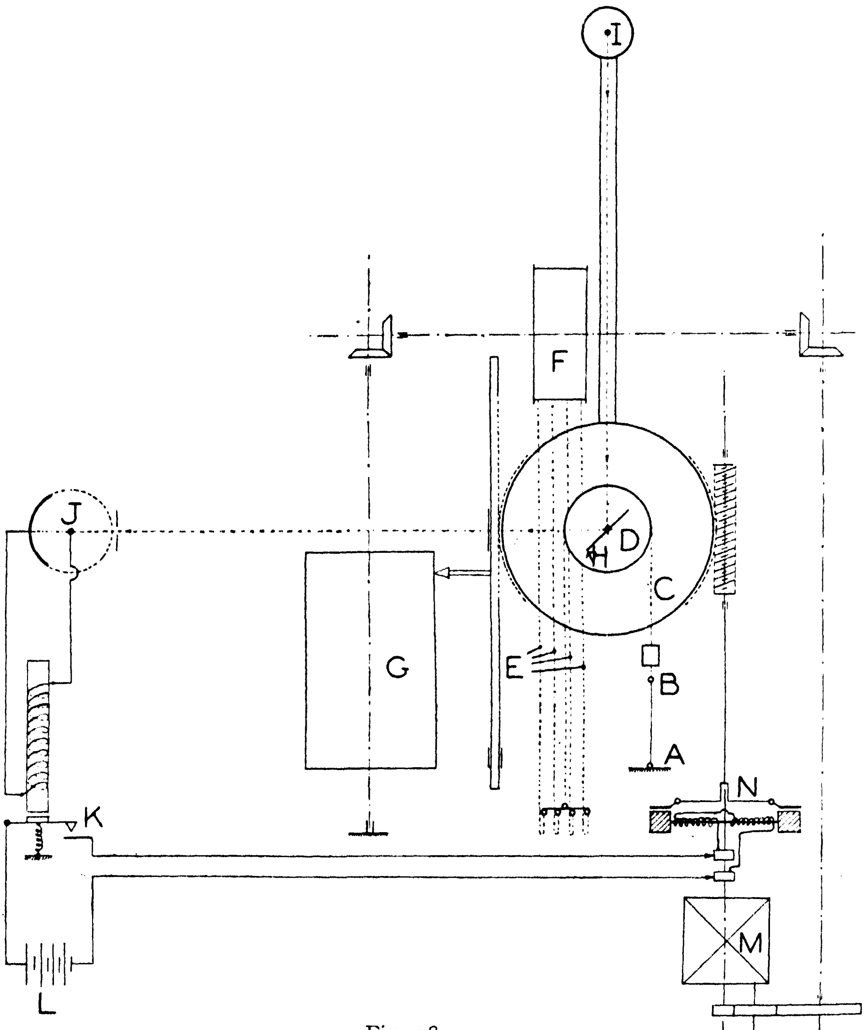


Fig. 18.

the fibre has a certain amount of elongation, and the distance covered by the pen will be less than that by the piston, and hence the curve drawn would be such as the line *b-b*. The distance *d* therefore represents the elongation, and *c* the strength. In this apparatus, of course, the friction between the pen and the paper introduces an error. The instrument by Aoki and Atsuki is specially designed to avoid the question of friction.

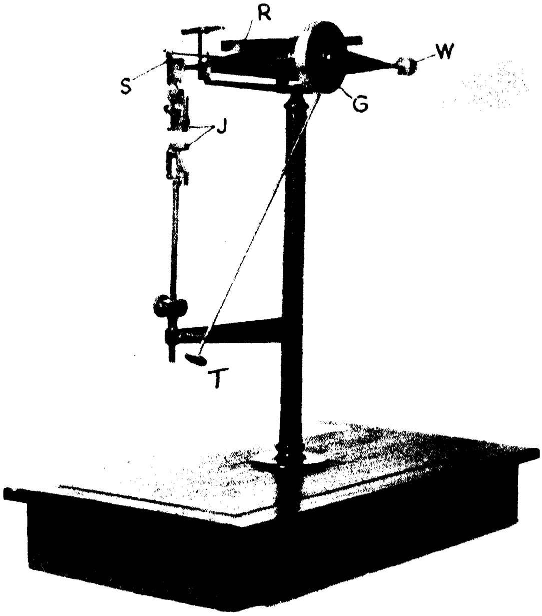


Fig. 3.

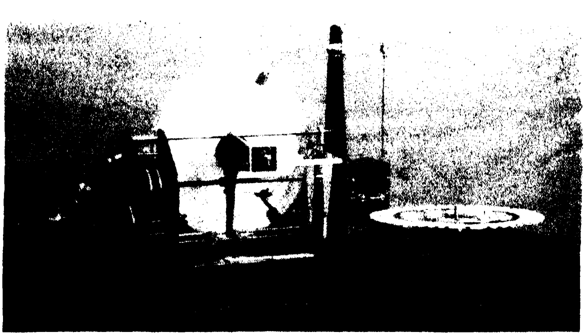


Fig. 7.

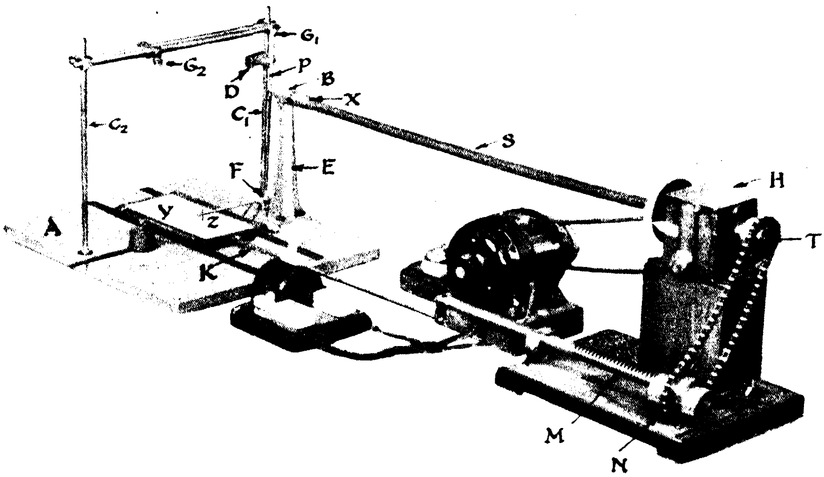


FIG. 13.

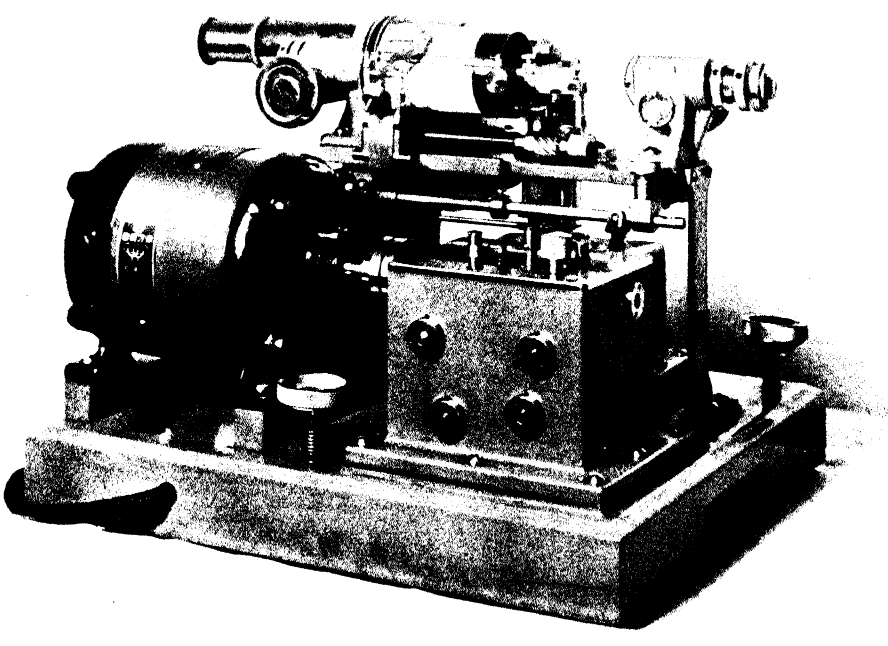


FIG. 25.

Instead of using a pen and paper the improved instrument by Aoki and Atsuki employs the method of photography. The positions of the terminals of the fibre are projected on to the sensitized paper wrapped around the drum which is turned by the string attached to the lower terminal of the fibre. Fig. 12 illustrates a diagram drawn from a photograph taken by the apparatus. XX' represents the elongation of the spring and hence the tension in the fibre. XY denotes the initial length of the fibre and $X'Y$ the elongation. The curve drawn by this apparatus, however, is not to the familiar rectangular co-ordinates. There would be with a short specimen a considerable error introduced in the reading of the elongation.

The tester by Cliff shown in Fig. 13 gives a diagram referred to in rectangular co-ordinates.

The specimen is held in the grips G_1 and G_2 in Figures 13 and 14. The arms a and b swing about their axle X, and the pen holder with the pen Z is loosely attached on b at F. One of the terminals of the spring S is fixed to X, which is supported by the bearing B, and the other terminal is connected with T, which is driven by the motor through the reduction gears and is also connected by a chain to the geared screw N. When T is driven by the motor, the arms a and b are rotated and tension is applied to the fibre. The moment due to the tension in the fibre is balanced by the torsion of the spring S. Neglecting the angle of rotation of the arms due to the elongation of the fibre, the angle of rotation of T is then proportional to the strength of the fibre. The recording board Y is moved through a distance proportional to the rotation of T in the direction perpendicular to the motion of the pen by means of the chain, geared nut N and the connecting rod K. While the strength of a fibre is thus indicated by the motion of the recording board, the elongation is indicated by the displacement of the pen perpendicular to that of the board. Hence, the curve would be drawn to rectangular co-ordinates with a uniform scale.

Owing to the friction at the bearing B and between the pen and the paper,* and to the fact that it is quite bulky in size, the apparatus as described can hardly be considered as having shown much progress.

To serve the same purpose an apparatus has been designed by D. Demeulemeester and I. Nicoloff,[16] of which the principle is illustrated in Figs. 15, 16, and 17.

AB represents the fibre to be tested. From B to E around the pulley D extends a single chain C, and from E to the loading drum G there are four chains F. It is assumed that there is no friction in the drum bearings, and the chains are of uniform weight per unit length. If the fibre AB is elongated by αr, B would be moved up and E down by this amount, while the lower end of F would be lowered by only $\frac{\alpha r}{2}$. The lifting of B by the distance αr results in the decrease of the weight at the right side of the pulley D by $P\alpha r$ while at the left side there results a decrease of $4P\frac{\alpha r}{2}-P\alpha r=P\alpha r$, where P stands for the weight of the chain per unit length. Therefore, the elongation of the fibre does not affect the equilibrium of the drum D. Now by turning the loading drum G clockwise through an angle β the weight of the chains unwound will be $4\beta RP$ and the increase in the load

*Cliff shows this to be negligible.—EDITOR.

on the fibre be $2\beta RP$. Thus it is evident that the load applied to the fibre will be proportional to the angle of the rotation of the drum G. Referring to Fig. 17, the drum H, which is covered with sensitized paper, is turned by means of bevel gears through the same angle as the drum G. The elongation αr of the fibre is indicated by the displacement of the slit I' in the board I which is suspended in front of the drum H from the side of D' which is fixed on the pulley D. J represents the source of light. Although the record in this case is drawn to rectangular co-ordinates with a uniform scale, the error due to the friction in the pulley D would be considerable.

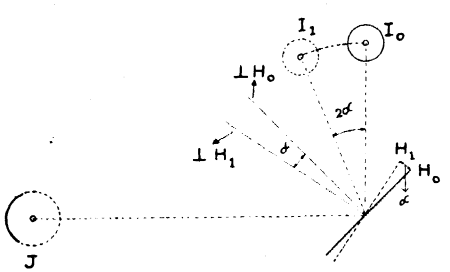


FIG. 19.

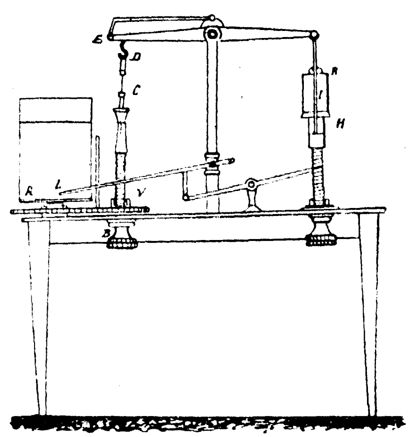


FIG. 20.

Further errors may be introduced if the weights of the chains are not perfectly uniform throughout their lengths and by the power necessary to fold the chains.

The apparatus shown in Fig. 18[17] embodies the same principle as the one just described, differing only in its employing a pen and ink instead of photography. The light from the lamp I attached to the geared wheel which turns loosely about the axle of the pulley D is reflected by the mirror H mounted on the pulley and throws the beam on the photo-electric cell J. Through a relay the photo-electric cell energizes the magnetic gearing N and moves the lamp as well as the recording pen. By means of the motor M the loading drum F and the recording drum G are turned, the motor being transmitted by the connecting rods and bevel-gears, while the fibre is being loaded and elongated, and hence the pulley is turned through a certain angle. Assume that the mirror H in Fig. 19 is rotated through the angle α and the light from the lamp I is thrown off the photo-electric cell J. Then, through a relay the switch K is instantly closed to engage the clutch N and rotate the worm-gear and the geared wheel C so that the lamp and the pen are moved until the lamp covers the angle 2α when J is again brought under the beam and opens the switch. Thus the strength and elongation of a fibre are mechanically recorded by the pen on a paper. Both the pieces of apparatus shown in Fig. 17 and Fig. 18 are of considerable size and are not very simple in their operation.

The testing apparatus of Heim Richard designed to overcome the effect of friction between the recording pen and the paper is similar in principle

to the O'Neill type in Fig. 1 for measuring the tension but differs by having a recording device.

Fig. 20 shows a diagram of the apparatus. The fibre is clamped in between C and D. I is the weight suspended in the mercury vessel K, which may be lowered by unscrewing the supporting bolt in order to apply a tension to the fibre. As the bolt is unscrewed the pen L is moved by means of a lever mechanism in the axial direction of the drum A and it moves through a distance proportional to the tension. At the same time C, the lower terminal of the fibre, is lowered through a distance equal to the elongation of the fibre, the upper terminal D being kept stationary. The displacement of C is communicated to the drum through gearing mechanism. In order to obtain an accurate result it is necessary to maintain constant the original position of D. Unless this is assured, though it is difficult, the elongation is incorrectly recorded when the fibre is short.

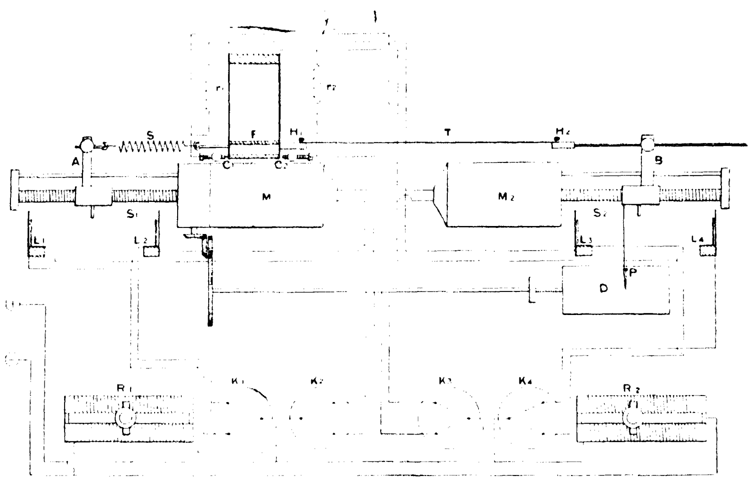


FIG. 21.

The diagram in Fig. 21 illustrates the tester by Barker and Tunstall.[18] The fibre to be tested is placed between the holders H_1 and H_2. The elongation of the spring S represents the tension in the fibre. The piece F attached to the holder H_1 is located between the two electrodes C_1 and C_2. M and M_2 denote the motors. The motor M drives the screw S_1 and by moving A it develops a tension in the spring, and at the same time it turns the recording drum D by means of the gears and the connecting rod D. The component of the curve perpendicular to the axis of the drum represents the tension of the fibre. The motor M_2 tends to move H_2 to the right. Since H_1 is located between C_1 and C_2, the displacement of H_2 and hence that of P, which is rigidly connected with H_2, represents the elongation of the fibre, provided H_1 has no play. This apparatus is quite involved, and as possible gaps between C_1 and F and C_2 and F are clearly the sources of errors, a fibre to be tested by this apparatus must be of a considerable length.

IV. RECORDING FIBRE TESTER DEVELOPED BY THE AUTHORS

From the above brief descriptions of and comments on the various testers, it will be noted that none can be considered ideal. A perfect tester must satisfy all the following requirements :—

(1) In testing the strength it must be very sensitive and free from the effect of friction.
(2). The elongation must be observed as magnified.
(3) The curve must be drawn to rectangular co-ordinates with uniform scales.
(4) It must be simple in both making and handling.

With these requirements in mind the present authors have invented a recording fibre tester as illustrated in Figs. 22, 23, and 24. The fibre to

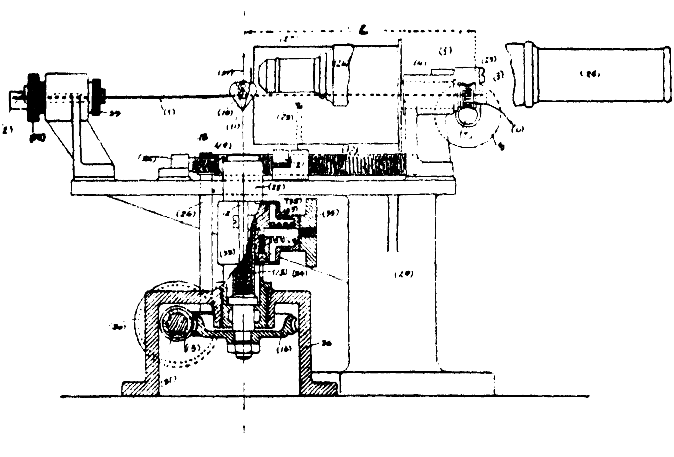


FIG. 22.

be tested is held between the grip (11) at the free end of the arm (10) and the lower grip (12). The wire (1) which is stretched between the holders (2) and (3) and is rigidly attached to the arm (10) by means of (9) at its mid-point is twisted in order to balance the tension in the fibre. By measuring, therefore, the angle of the twist of the wire due to the torsion the strength of the fibre may be known. By rotating the pulley (30) through the reduction gears in the box (36), the lower grip (12) is lowered with a uniform speed so that tension is developed in the fibre and the upper grip (11) tends to follow the pull. In order to maintain the upper grip in its original position of (11) the knob (8) is turned in such a direction that the wire is twisted in the counterclockwise direction until its moment just balances that due to the tension in the fibre. As the wire holder (3) and the recording drum (27) form one body, the angle of rotation of (3) and the component of the curve perpendicular to the axis of the drum represent the strength of the fibre. The principle of the apparatus is thus similar to that designed by Cliff. In the new apparatus, however,

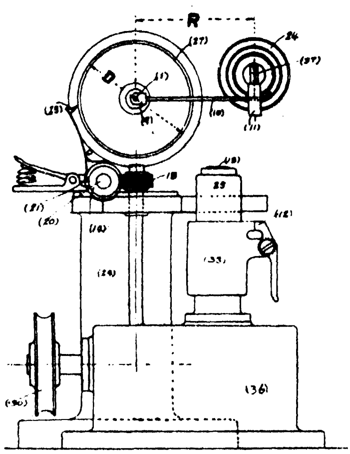


FIG. 23.

the friction in the bearing (5), between the gears (6) and (7), and between the pen (23) and the recording drum (27) have little effect on the record and besides, by proper selection of the wire any degree of sensitivity may be obtained.

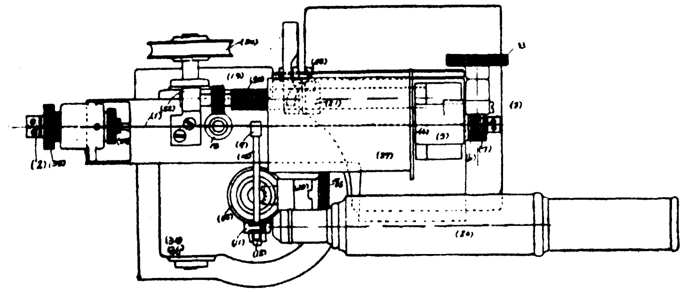


FIG. 24.

The pen (23) is mechanically connected with (12) and moves over the drum (27) in its axial direction, the speed of which may be set to any desired rate by simply changing the gear ratio. If the upper terminal of the fibre is held stationary, the downward displacement of the lower terminal (12) is equal to the amount of the elongation of the fibre. Hence, the displacement of the pen must be equal to the elongation of the fibre multiplied by the speed ratio of the mechanism. This scheme resembles those of Polanyi and of Heim Richard, but Polanyi's neglects the displacement of the upper terminal while Richard's lacks the device to observe it accurately. Hence,

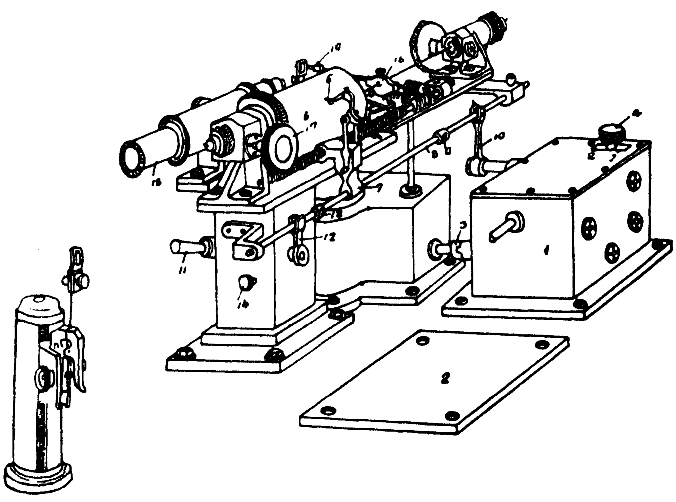


FIG. 26.

in these designs, whatever the magnification may be, it is useless, since the error due to the shifting of the upper terminal is equally magnified. The greater the magnification, the closer the observation of the upper terminal of the fibre must be required. In this new apparatus the magnoscope (25)

is adapted to serve the purpose, and is rigidly mounted on the frame. Watching through the magnoscope and by turning the knob (8), an operator is able to maintain the original position of the mark (37) on the upper terminal (11). This device is one of the new features of the apparatus. It is also clear from the precious description that the form of recording gives uniform scales to rectangular co-ordinates. Therefore the requirements (2) and (3) are also fulfilled by this apparatus.

In this instrument the employment of any moving joint in the strength indicating mechanism has been avoided in order to simplify its construction as well as its manipulation and the use of sensitized paper is avoided. Thus the requirement (4) is again met by the apparatus.

The latest improved type of the instrument due to the present authors is illustrated in Figs. 25 and 26. The speed of the motor mounted on the base (2) is reduced by the gears in the box (1) and transmitted to the shaft (3). By changing the position of the handle (4) it is possible to obtain one of the

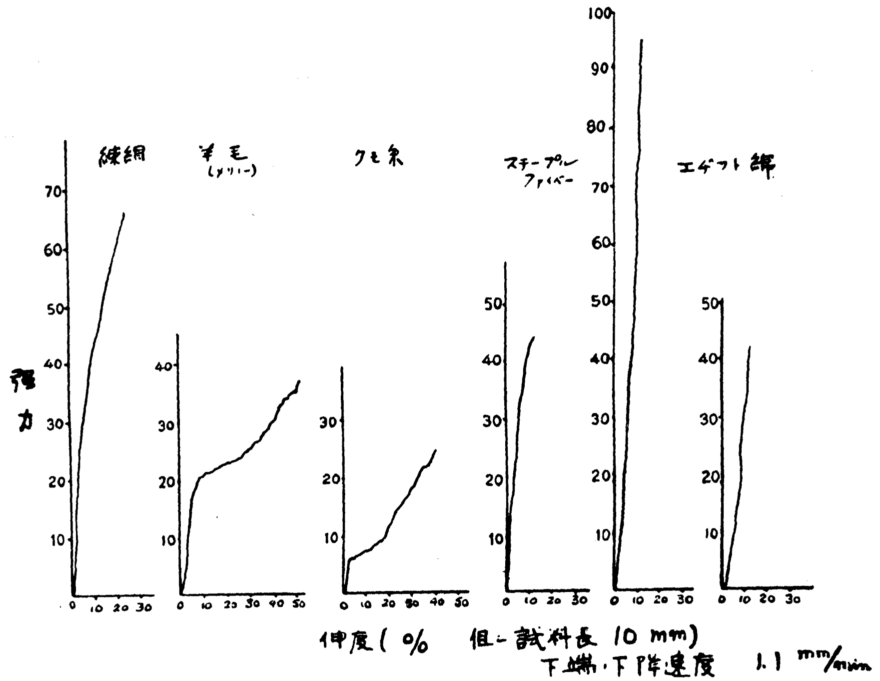


FIG. 27A.

two different speeds for application of a load to the fibre. The pen (5) draws the curve on the drum (6). The piece (7) to which the pen is attached, slides along the rod (8), and when (7) hits (9), (8) works on the lever (10) which in turn releases the clutch and stops the rotation of the shaft (3) so that it prevents the pen from running too far and breaking the machine. For the lever (10) there are three different positions, namely normal, stop and reverse. After an experiment, the pen and the lower grip must be returned to their original positions before the next operation, and for the control there is the handle (11). By working the handle the lever (10) is

set by means of the rod (8) to the reverse position, and the shaft (3) then starts turning in the opposite direction at a higher speed so that (5) and (7) quickly return to their initial positions, and as (7) strikes (13), (10) is again brought to its stop position.

This apparatus is so sensitive that when a test-piece is placed in the position the upper grip keeps vibrating for a considerable length of time. In order to stop this, the knob (14) is turned in one direction so that by a cam the prong support (15) is raised, on which (16) comes to rest and instantly stops the vibration. When all the preparations are made and just before starting the test, the knob is slowly turned back so that (16) is set free. A and B of Fig. 27 show the records obtained by means of the apparatus employing the different wire and gear ratio for each.

During the test, as it has already been mentioned, one is required constantly to turn the adjusting knob (8) while watching the mark (37) through the magnoscope in order to keep the upper terminal of the fibre steady. Although it may depend upon the skill of the operators, the authors considered the loading speed ranging from 0·05 mm/min. to 2·2 mm/min. the most satisfactory and desirable, and the apparatus has been so designed.

In some cases there may be no necessity of keeping a complete record from the beginning to the end of a test, but only of the maximum values of the strength and elongation. This can be readily performed by the apparatus without the aid of the operating motor. After properly placing

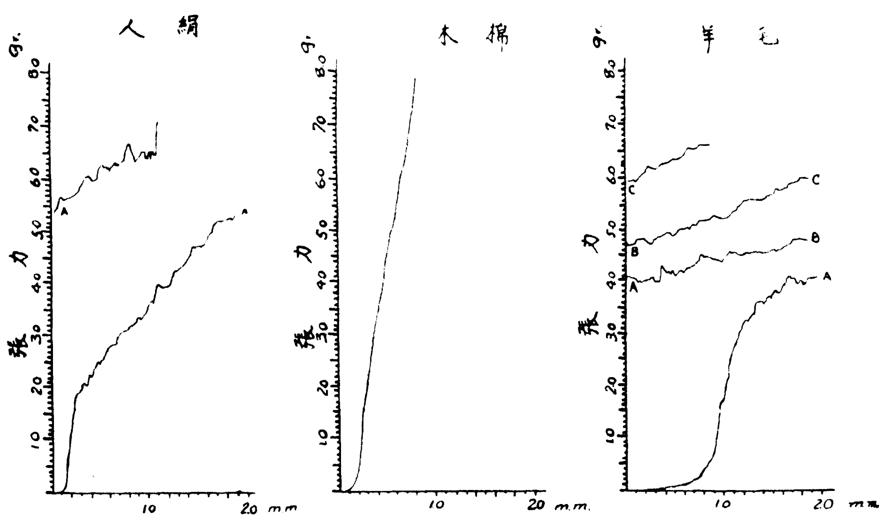


FIG. 27B.

a test-piece, in testing for the strength simply turn the knob (17) without paying attention to anything until the fibre breaks. Then read the angle of the rotation of the drum (6) from which the maximum strength of the fibre may be known. For testing for the maximum elongation of a fibre, place the graduated scale within the magnoscope and read the displacement of the upper grip (19). From this reading the maximum elongation may be calculated. Thus the experiments can be performed readily and easily.

REFERENCES

[1] C. O'Neill. *Mem. Lit. & Phil. Soc.*, Manchester, Nov. 17, 1863.

[2] " Development and Properties of Raw Cotton." W. L. Balls, London, 1915, p. 189.

[3] J. C. Mann and F. T. Peirce. *J. Text. Inst.*, 1926, **27**, T82.

[4] " Structure of the Cotton Fibre." F. H. Bowman, London, 1908, p. 264.

[5] " Textile Fibres." J. M. Matthews, 1916, p. 254.

[6] T. Barratt. *J. Text. Inst.*, 1922, **13**. T17.

[7] P. Krais. *J. Text. Inst.*, 1928, **19**, T32.

[8] Richard Heim. For a description of this apparatus see Weltzein and Coordt, *Seide*, 1932, **37**, 276.

[9] Tänzer. *Textilber.*, 1927, **8**, pp. 858, 938, 1,013.

[10] W. L. Balls. " The Development and Properties of Raw Cotton." London, 1915, p. 190.

[11] S. A. Shorter and W. J. Hall. *J. Text. Inst.*, 1923, **14**, T493.

[12] Polanyi. *Z. Tech. Physik.*, 1925, **6**, p. 121.

[13] Denham and Lonsdale. *J. Sci. Instruments*, 1928, **5**, 348.

[14] Aoki and Atsuki. *J. Soc. Chem. Ind. Japan*, 1930, **33**, 383B.

[15] H. S. Cliff. *J. Text. Inst.*, 1933, **24**, T351.

[16] D. Demeulemeester and I. Nicoloff. *J. Text. Inst.*, 1935, **26**, T147.

[17] D. Demeulemeester and I. Nicoloff. *J. Text. Inst.*, 1936, **27**, T84.

[18] S. G. Barker and Tunstall. *Trans. Faraday Soc.*, 1929, **25**, p. 103.

Acknowledgments. Fig. 21 is reproduced by courtesy of the Faraday Society and Fig. 7. by that of the Fine Spinners and Doublers Association.

Received 2/2/37.

9—A PORTABLE ULTRA-VIOLET FLUORESCENCE LAMP FOR THE EXAMINATION OF TEXTILE AND OTHER MATERIALS

By D. A. Derrett-Smith

INTRODUCTION

In the course of the examination of a considerable number of defects in textile materials, valuable help in forming an opinion as to the cause of such faults has frequently been obtained by examination of the material in ultra-violet light.

The present paper describes a small portable ultra-violet fluorescence outfit which has been designed for this type of work. It enables the material under examination to be " scanned " with ultra-violet light, the lamp being brought to the material instead of the material to the lamp as is the case with the fixed types of fluorescence apparatus.

PART I. THE CONSTRUCTION OF THE LAMP

A small quartz mercury vapour burner is employed in the apparatus. It is of the discharge type and is manufactured by The Thermal Syndicate, Ltd., Wallsend, Northumberland, for therapeutic purposes, under the name of the " Vi-tan " burner. It consists of a " U " tube of transparent quartz (" Vitreosil ") furnished with solid metal electrodes and containing mercury and neon gas. The latter is an exciter gas used for starting purposes and when the burner is switched on from cold the characteristic red colour of the neon discharge is produced. After about half a minute the colour has changed to the bluish-green of the mercury vapour discharge. Unlike the older arc type of mercury vapour burner with mercury electrodes, it can be used in any position.

The spectral characteristics of the burner are shown in Fig. 1, from which it is seen that, in addition to radiation of wave-length about 2540 A.U., it yields an appreciable intensity of radiation of wave-lengths between about 3000 and 4000 A.U., a band which is transmitted by a number of glasses which absorb the majority of visible radiations. Among these are Wood's Glass, Uviol Glass and Chance's Ultra-Violet Filter Glass No. 14. A typical transmission curve for Chance's Ultra-Violet Glass at a thickness of 2 mm. is shown in Fig. 2. By means of this filter the band of wave-lengths between 3000 and 4000 A.U. may be made available for fluorescence tests. It is to be noted that fluorescence may be excited by radiation of wave-lengths smaller than 3000 A.U. and while radiation of such wave lengths can undoubtedly produce a greater degree of fluorescence than those in the 3000-4000 A.U. band (cf. fluorescence of cellulose[1]) and may possibly enable further analytical differentiations to be made, the latter band as transmitted by the Ultra-Violet Filter glasses referred to above forms the most convenient source of excitation at present available.

The " Vitan " burner was considered attractive for use in the apparatus from the following points of view :—

1. It yields sufficient intensity of radiation of wave-lengths between 3000 and 4000 A.U.
2. It is manufactured in considerable quantities and may, therefore, be regarded as a standardised product.
3. It is reasonably low in price.

4. Its current consumption is small, being of the order of 50 watts and it gives out very little heat.

5. It may be used in any position.

6. It is stated by the makers that in consequence of the small amount of mercury which the burner contains, it cannot break through mercury " hammer."

The life of a typical " Vitan " burner is shown by the following figures kindly supplied by the manufacturers.

Table I

Variation of Intensity of " Vitan " Burner with Time.

Time (hours).	Total intensity as % of initial intensity	Volts across burner	Burner current max.
0·5	100·0	350	137
5·0	112·0	335	137
21·0	91·0	335	137
441·0	83·7	335	137·5
777·0	110·0	329	137·5
1117·0	103·0	318	138·0

It will be seen that after the drop in intensity at 441 hours, the intensity after 1117 hours is approximately equal to the initial value.

Fig. 3 shows side and front views of the apparatus. The burner is placed inside a metal housing, a chromium-plated reflector being placed immediately behind it. In front is placed a sheet of Chance's Ultra-Violet Filter Glass No. 14. The robust handle attached to the back of the housing enables the lamp to be moved easily over the surface of the material under examination. A cast iron base allows the lamp to be set down when not in use. Fig. 4 shows a general view of the lamp.*

The burner operates from an A.C. supply through a suitable transformer which is arranged as a portable unit. As will be seen from Table I, the actual measured voltage across the burner when in operation is about 350. Tappings are provided on the transformer so that it can be connected to A.C. mains of any voltage between 200 and 250.

It is necessary to make observations in a dark or darkened room. Part of a room screened off with black curtains forms a suitable place.

The use of goggles when making observations.

Radiation of wave-length below 3400 A.U. such as is transmitted by the Ultra-Violet Filter Glass used in the apparatus (see Fig. 2) may have undesirable effects on the eyes especially if observations are made for protracted periods, and it is advisable to wear goggles containing glass which will absorb these radiations. This glass must be as nearly colourless as possible in order not to interfere with the examination of fluorescence colours. The majority of ordinary commercial glasses, for example window glass, of moderate thickness (about 2 mm.) and especially the so-called flint glasses absorb most of the rays shorter than 3400 A.U. and may be used for the goggles. Crookes glass " A " absorbs almost completely from about 3600 A.U. and is preferable for this reason.

* The lamp may be obtained from The Thermal Syndicate Ltd., Wallsend, Northumberland.

PART II. APPLICATIONS OF ULTRA-VIOLET RADIATION IN THE EXAMINATION OF TEXTILE MATERIALS

Of the large number of uses to which it has been suggested that ultra-violet radiation from 3000-4000 A.U. may be put, a few of the more important applications from the textile point of view are considered below.

1. The Examination of Oils, Fats and Waxes under the Lamp.

It has been known for some years that certain mineral or paraffin oils fluoresce with a brilliant reddish-blue colour in ultra-violet light and that other oils vary in the ultra-violet fluorescence colours which they yield, from blue to yellow.

Experimental.

Samples of bleached linen and cotton and of grey linen and cotton* were impregnated with known weights (bleached and grey linen 44-45 per cent. ; bleached and grey cotton 73-75 per cent.) of a number of commercial oils and fats, drying, semi-drying and non-drying, and examined after a period of 62 days between November 1936 and January 1937. One half of the sample in each case was suspended by means of wooden clothes pegs from cord strung up in a room illuminated only by artificial (electric) light. The other half was exposed to daylight in front of a closed window in the laboratory facing east, the samples being similarly suspended by pegs from cord strung across the inside of the window frame. The light exposure commenced seven days after the application of the oil, etc., in each case. Untreated samples of the fabrics were included for control purposes.

The following table gives an approximate description of the appearance under the lamp of the bleached linen and cotton samples before and after treatment.

Slight differences only were observable between the treated bleached linen and bleached cotton in each case and these are not recorded.

The grey cotton gave similar relative results but the greenish-yellow fluorescence of the untreated material interfered in most cases with the fluorescence of the fatty substances. The grey linen, except in the cases where the oil or fat added showed a bright fluorescence such, for example, as the pale mineral oil and the heavy lubricating oil, showed a dark indefinite colour under the lamp.

In order to examine more precisely the fluorescence colours of the fatty materials in these cases, portions of the treated samples were placed on filter paper which was in turn placed on a clean white glazed tile and spotted with a few drops of hot Carbon Tetrachloride (ANALAR). Extraction of the fat is usually facilitated by slight pressure for a few moments with two thicknesses of filter paper from above. Too much pressure is undesirable as it may result in the transfer of sufficient of the natural fatty impurities of the grey fabric to the filter paper beneath to interfere with the fluorescence colours.

---

* Particulars of these cloths are as follows :—

	Ends per inch	Picks per inch	Lea of Yarn Warp	Lea of Yarn Weft	Solubility No. (Cloth)
Bleached Linen ...	68	64	52's	53's	6·5
Bleached Cotton ...	45	42	11's	11's	2·4
Grey Linen	40	36	25's	20's	—
Grey Cotton	44	42	10's	10's	—

Table II

Appearance under the lamp of bleached linen and bleached cotton cloth before and after treatment with various oils and fats.

Oil or Fat.	Type.	Appearance under the Lamp		
		Immediately.	After 62 days: In dark room with artificial light	After 62 days: In daylight
Untreated Controls	Bleached Linen Bleached Cotton	Slightly Blue Slightly Blue (very slightly darker, if anything, than linen)	Similar Similar	Similar Similar
Linseed Oil (raw)	Drying	Yellow	Greenish-yellow	Slightly greener and brighter
Linseed Oil (twice boiled)	Drying	Yellow (brighter than raw linseed oil)	Greenish-yellow	Slightly more bluish
Soya Bean Oil	Drying	Blue	Greenish-yellow	Slightly bluish-green
China Wood Oil (Tung Oil)	Drying	Greenish-blue	Yellowish	Slightly greenish-yellow
Rape Oil	Semi-drying	Blue	Greenish-blue	Greenish-yellow
Cottonseed Oil	Semi-drying	Brightish blue	Greenish-yellow	Duller, slightly greener yellow
Mineral Oil (water white) Wijs Iodine value < 1	Non-drying	Very little effect	Distinctly bluer	Brighter and rather greener
Mineral Oil (pale) Wijs Iodine value = 10	Non-drying	Bright blue	Slightly more greenish-blue	Deep golden yellow
Mineral Oil (very dark lubricating oil)	Non-drying	Bright golden yellow	Very slightly darker	Considerably darker brownish-yellow
Sperm Oil	Non-drying	Faint yellow	Greener	Bluish-green
Olive Oil (edible)	Non-drying	Slight blue (reddish tinge)	Brighter blue	Brighter and slightly greener blue
Lard Oil	Non-drying	Brightish blue	Greenish-blue	Greenish-yellow
Neatsfoot Oil	Non-drying	Pale reddish-blue	Slightly greener	Definitely greener
Castor Oil	Non-drying	Blue	Greenish-blue	Greenish-yellow, brighter
Sulphonated Castor Oil (44% moisture; treated fabrics air-dried)	Non-drying	Pale reddish-blue	Brighter greenish-blue	Slightly greener

Table II—Continued.

Oil or Fat	Type	Appearance under the Lamp		
		Immediately	After 62 days	
			In dark room with artificial light	In daylight
Coconut Oil	Non-drying	Reddish-blue	Brighter—slightly greener	Definitely greener
Palm Oil (raw)	Non-drying	Bright bluish-green	Bright bluish-green	Brownish-yellow
Palm Oil (bleached)	Non-drying	Blue	Slightly greener	Blue
Tallow	Non-drying	Reddish-blue	Greener	Yellowish-green

Carbon Tetrachloride (ANALAR) was chosen as a suitable solvent, since on evaporation it leaves only minimal traces of fluorescent material. A blank test with it on filter paper shows under the lamp an area with a very faint blue boundary line. The grey cotton tested gave a very slight greenish-blue residue while the grey linen gave a slightly more pronounced bluish colour.

Carbon Tetrachloride spot tests were made on all the treated fabrics and it was found that the fluorescence colours of the spots from the treated bleached fabrics were, in all cases, very similar to those shown by the treated bleached fabrics themselves. In several instances, particularly where the oil or fat did not itself yield a bright fluorescence, the fluorescent material derived from the grey fabrics, the linen, was discernible but could be allowed for mentally by observing the fluorescence colour given by spotting the untreated fabric side by side with the treated fabric.*

This method of spotting is useful in detecting the presence of oils soluble in carbon tetrachloride, which may be present on heavily-dyed yarns or fabrics or associated with materials which inhibit the fluorescence of the oils.

It was found, however, that while the samples freshly treated with drying oils gave a satisfactory spot, those after ageing showed no appreciably greater spot fluorescence than was shown by the blank. This is doubtlessly due to the low solubility in carbon tetrachloride of the oxidised oils. It is interesting to note that cottonseed oil—a semi-drying oil, showed, after exposure, a faint spot of fluorescence colour only.

In addition to the experiment described above, discs of filter paper (Whatman No. 5) were spotted with a few drops of a number of oils, fats and waxes (including those already examined) and hung up close to a window in the laboratory facing east. The appearance of the spots after 49 days exposure (December 1st, 1936-January 19th, 1937) was compared with that of the spots immediately after application. The results are given in the following table :—

* More prolonged extraction of grey flax with carbon tetrachloride may lead to the production of a greenish coloured solution the residue from which may show a reddish-blue or even reddish fluorescence due to the extraction of chlorophyll which itself shows a characteristic red fluorescence.

Table III
Appearance under the Lamp, before and after exposure to light, of various oils, fats and waxes spotted on to filter paper.

Material applied.	Appearance under Lamp. Immediately.	Appearance under Lamp. After 49 days exposure to daylight.
Untreated	Dark reddish-blue.	Brighter blue—slightly greener round edges.
Linseed Oil (raw).	Yellow.	Bluish-green.
Linseed Oil (twice boiled)	Yellow (brighter than raw linseed oil).	Slightly bluer.
Soya Bean Oil.	Blue.	Greenish-blue.
China Wood Oil (Tung Oil).	Greenish-blue.	Greener.
Rape Oil.	Blue.	Greener blue.
Cottonseed Oil.	Blue.	Bluish-green.
Mineral Oil (water white). Wijs Iodine value < 1.	Very little effect.	Slightly bluer.
Mineral Oil (pale). Wijs Iodine value $= 10$.	Bright blue.	Yellow.
Mineral Oil. (very dark lubricating oil).	Bright golden-yellow.	Brown.
Mineral Oil. (gear oil, Mobiloil C.)	Brownish-yellow.	Slightly darker brown.
Sperm Oil.	Yellowish.	Slightly bluish.
Olive Oil (edible)	Very pale blue, brownish tinge.	Pale blue.
Lard Oil.	Pale blue.	Greener.
Neatsfoot Oil.	Very pale blue.	Slightly yellower.
Castor Oil.	Pale blue.	Slightly greener.
Sulphonated Castor Oil (after drying).	Blue.	Slightly paler blue.
Coconut Oil.	Pale blue.	Slightly greener.
Palm Oil (raw)	Bright greenish-yellow.	Golden brown.
Palm Oil (bleached)	Greenish-blue.	Very slightly greener.
Tallow.	Blue.	Yellowish-green.
Pine Oil	Faint blue.	Greenish-yellow.
Turpentine.	Very faint blue edge.	Small greenish-yellow spot.
Petroleum Jelly (yellow).	Bright blue.	Yellow.
Petroleum Jelly (white).	Very bright blue.	Yellow.
Paraffin Wax (yellow) (M.P. 105° F.) Wijs Iodine value $= 5{\cdot}7$	Whitish-blue.	Brownish-yellow.
Paraffin Wax (white). (M.P. 112° F.) Wijs Iodine value 1·2.	Whitish-blue.	Brownish-yellow.

Discussion of Results of the Examination of the oils, fats, waxes under the lamp.

The changes observed in the fluorescence colours are, in the majority of cases, more pronounced as a result of ageing in daylight than in artificial (electric) light.

Certain mineral oils and fats, viz. pale mineral lubricating oil, petroleum jelly (yellow) and petroleum jelly (white) exhibit an intense blue fluorescence which changes on ageing in daylight to a yellow. The blue colour is considered to be due to the presence of unsaturated constituents which become oxidised on ageing. Paraffin wax M.P. 105° F. (yellow) and 112° F. (white) both show a whitish-blue fluorescence which likewise becomes yellow on ageing.

In the heavy mineral lubricating oils examined, this blue fluorescence, however, is absent, these oils appearing bright yellow under the lamp ; on ageing the fluorescence colour is merely darkened somewhat. As these oils represent the heavier fraction of petroleum it is possible that any unsaturated compounds which they may have contained became oxidised during distillation.

Linseed oil, especially after boiling, shows a definite yellow fluorescence and raw palm oil exhibits a bright greenish-yellow fluorescence changing to golden brown on exposure to daylight. This greenish-yellow fluorescence was not shown by the sample of bleached palm oil examined which suggests that the fluorescence may be due in some measure to the colouring matter present. The yellow fluorescence of linseed oil may be due partly to the same factor also.

It will be observed from the results given in Tables II and III that in a considerable number of cases the effect of the daylight exposure in particular has been to alter the fluorescence colours in the direction of yellow.

Several vegetable oils are now produced commercially by solvent extraction usually with solvents which themselves may show a blue fluorescence. Traces of the solvent remaining in the oil map mask the natural fluorescence colour of the latter. Oils now produced by solvent extraction include linseed, cottonseed, soya bean, rape and castor oils. It has been found that a solvent extracted oil or an oil which has been refined under pressure may exhibit a blue fluorescence, whereas oils obtained by expression usually exhibit a yellow or greenish fluorescence.[2]

It is clear, therefore, that the results of the examination under the lamp do not necessarily allow of the identification of an oil present, for example, as a stain on a textile material, but in conjunction with the spotting-through test described on page 147 the examination under the lamp yields valuable evidence. In the case of residues from drying oils which may not be readily soluble in carbon tetrachloride, the fluorescence (on the fabric) in conjunction with other tests gives useful evidence.

Figure 5 shows a badly oil-stained cotton collar cloth. The photograph was taken under the lamp in a dark room, a 30 per cent. solution of sodium nitrite being used as a filter for preventing short wave radiation transmitted by the camera lens from reaching the plate. A number of the stains were visible in ordinary light as yellowish patches but examination under the lamp revealed a much larger number as bluish fluorescent areas.

The examination under the lamp of fabrics in which oil stains in the weft yarn, for example, appear as pale brown bars, often enables an opinion to

be given regarding their origin since the fluorescence colours often reveal further local staining which is invisible in ordinary light. By this means the distribution of the stain can often be determined. In one case examined recently, an opinion was required as to the cause of a faint yellowish bar which appeared in the weft of a bleached linen damask napkin. Examination under the lamp revealed five separate bars fluorescing with a yellowish colour. Figure 6 shows one of the bars, not visible in ordinary light, photographed under the lamp. Adjacent to the bar the weft yarn is seen to have been stained discontinuously. In the investigation of this fault, the stained places in one of these bars as seen under the lamp were marked and the weft yarn removed. From the evidence obtained it was concluded that contamination of the weft yarn took place probably during winding.

2. The Examination of Dyed Materials under the Lamp.

A large number of dyestuffs when dyed on textile materials show fluorescence colours in varying degree when examined under the lamp, some dyestuffs showing especially brilliant effects. These colours are more apparent in medium to light shades being usually considerably darker in heavy shades.

The following tables indicate a number of dyestuffs which when dyed on bleached cotton and bleached linen show definite fluorescence colours. The depth of dyeing given is that at which the particular observation was made.

Table IV

Vat dyestuffs which show distinct fluorescence colours under the lamp.

Dyestuff	Material on which sample tested was dyed	Depth of Dyeing	Fluorescence Colour
Algol Yellow GC (I.G.) (Caledon Yellow 5GS (I.C.I.))	Bleached Linen and Boiled Cotton Yarn	4·5% double paste	Orange-yellow
Algol Yellow GR (I.G.)	Bleached Linen and Boiled Cotton Yarn	12·0% paste	Orange-yellow
Algol Yellow 3GK (I.G.)	Bleached Linen and Boiled Cotton Yarn	7·5% paste	Orange-yellow
Algol Scarlet 2G (I.G.)	Bleached Linen and Boiled Cotton Yarn	15·0% paste	Red
Caledon Yellow 3GS (I.C.I.) (Indanthrene Yellow GK (I.G.))	Bleached Linen and Boiled Cotton Yarn	8·0% paste	Orange-yellow
Cibanone Yellow 3GK (S.C.I.)	Bleached Linen and Boiled Cotton Yarn	15% paste	Orange-yellow
Cibanone Yellow R (S.C.I.)	Bleached Linen and Boiled Cotton Yarn	15% paste	Orange-yellow
Cibanone Orange R (S.C.I.)	Bleached Linen and Boiled Cotton Yarn	2% powder	Orange-red
Indanthrene Yellow 5GK (I.G.)	Bleached Linen and Boiled Cotton Yarn	3·0% powder	Orange-yellow
Indanthrene Yellow 7GK (I.G.)	Bleached Linen and Boiled Cotton Yarn	3% powder	Orange-yellow

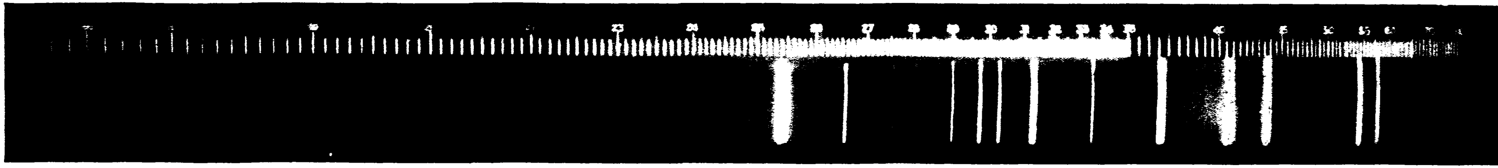


FIG. 1
Spectral Characteristics of "Vitan" Burner.

FIG. 5
Oil Stained Cotton Collar Cloth in Ultra-Violet Light.

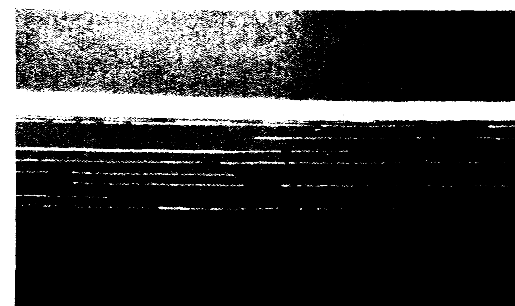
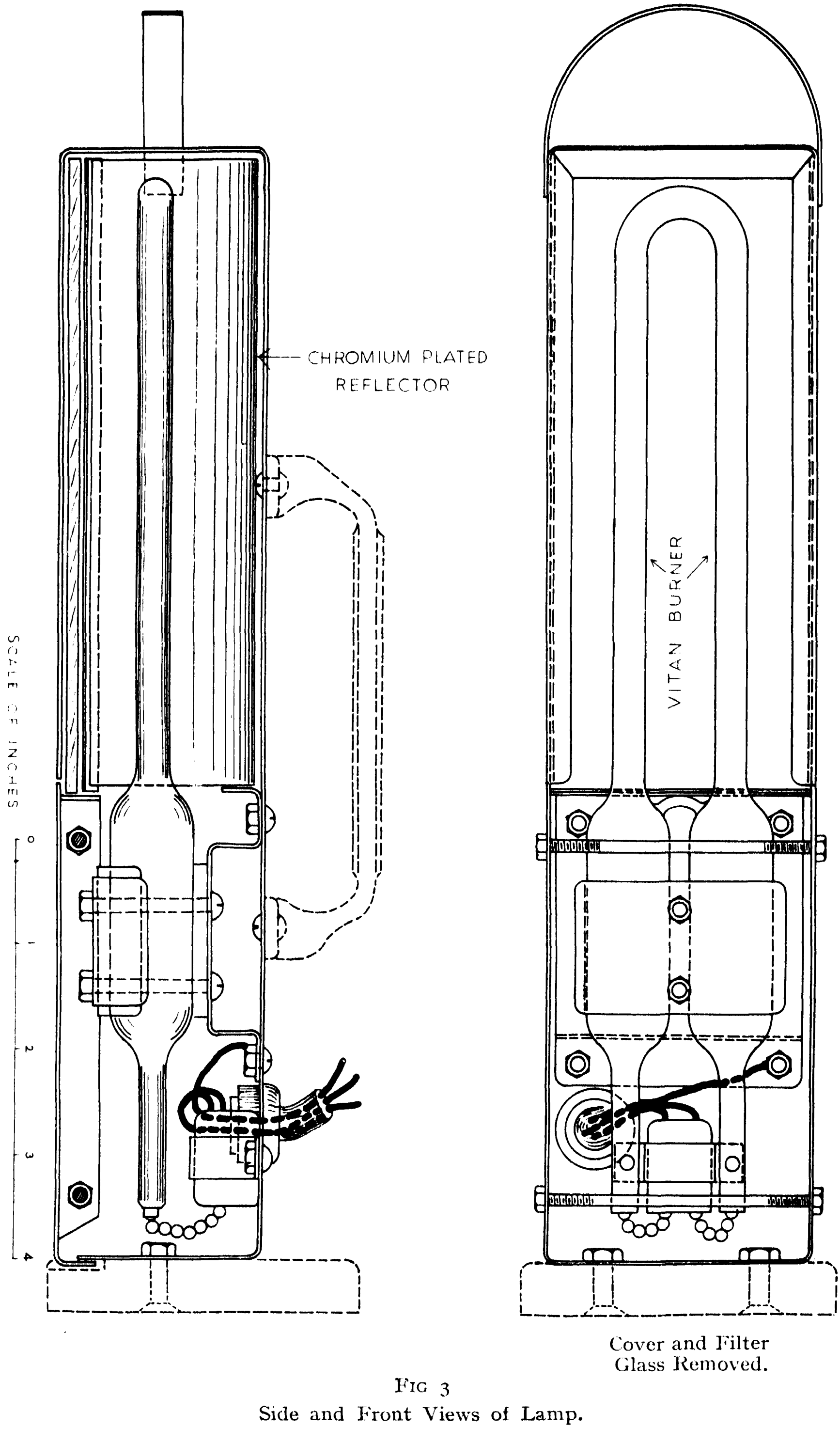


FIG. 6
Weft Bar in Bleached Damask Napkin under the Lamp.



Cover and Filter
Glass Removed.

FIG 3
Side and Front Views of Lamp.

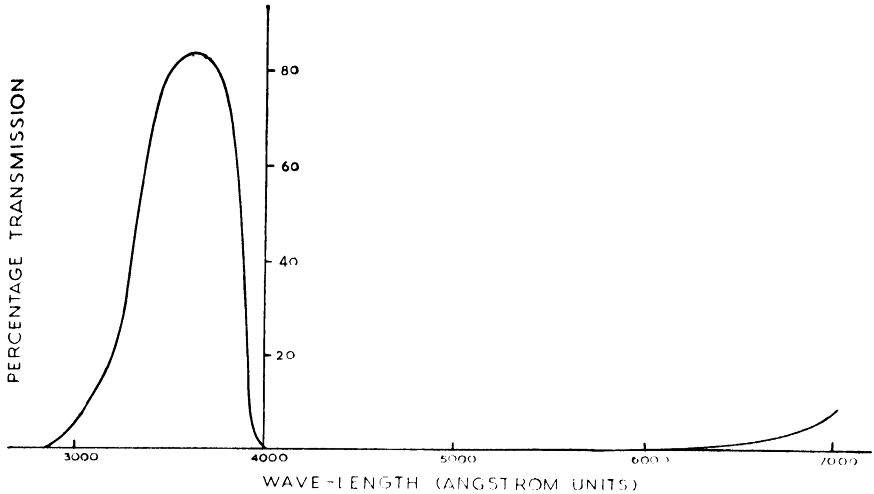


FIG. 2
Typical Transmission Curve of Chances Ultra-Violet Filter Glass No. 14. (Thickness = 2mm.)

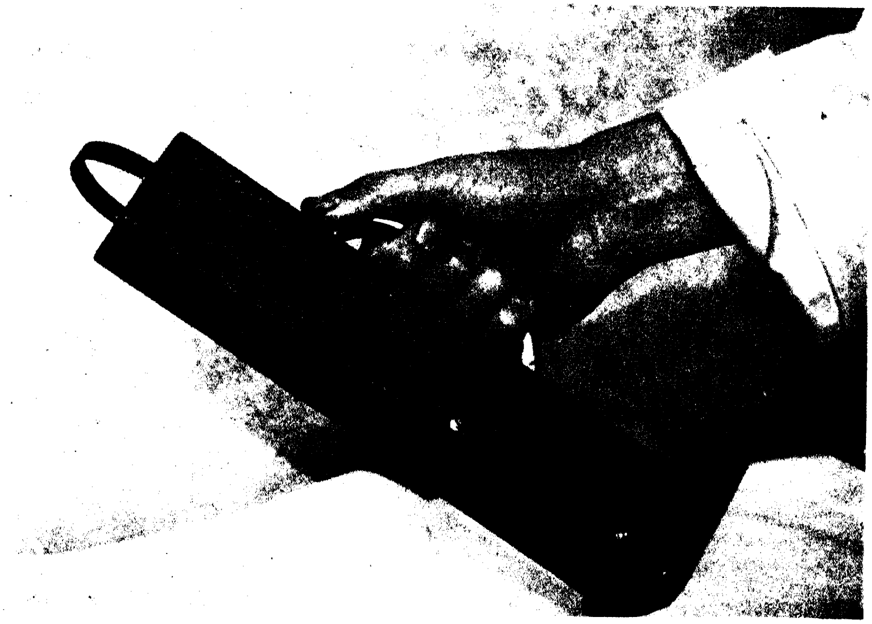
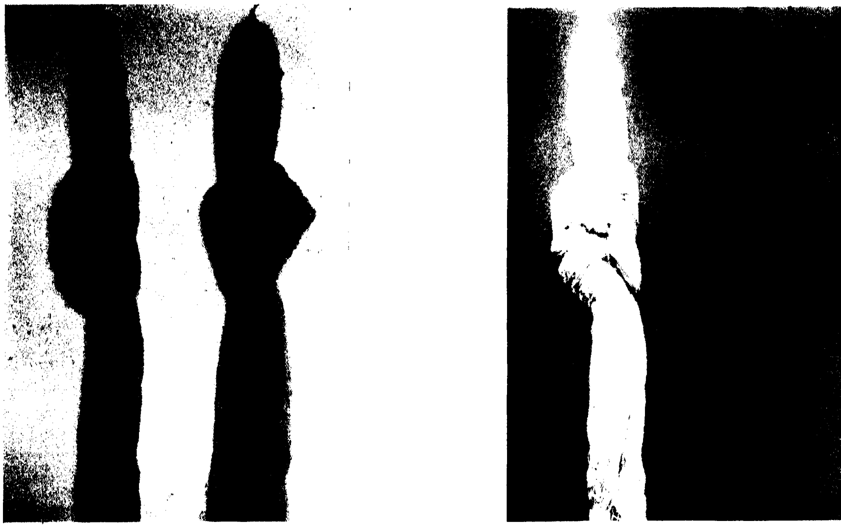


FIG. 4
General View of the Lamp.

A B



1 2 1 2

FIG 7
Hanks of Cotton Yarn Dyed with
1. Brilliant Dianil Green G.
2. Sirius Supra Green 2B.
Photographed in

A Daylight.

B Ultra-violet light.

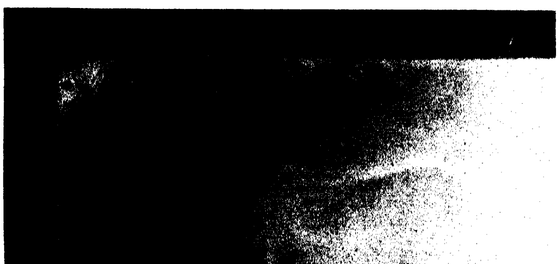


FIG 8
Bleached Linen Sheeting showing Mildew Spots and Tide-Mark near Selvedge photographed under the Lamp.

Table IV—Continued.

Dyestuff	Materia lon which sample tested was dyed	Depth of Dyeing	Fluorescence Colour
Indanthrene Golden Yellow GK (I.G.)	Bleached Linen and Boiled Cotton Yarn	2% powder	Orange-red
(distinct from Indanthrene Golden Yellow RK which appears considerably darker under the lamp).			
Indanthrene Brilliant Orange GR (I.G.)	Bleached Linen and Boiled Cotton Yarn	2·5% powder	Bright Orange-red
(distinct from Indanthrene Brilliant Orange GK and RK, both of which appear considerably darker under the lamp).			
Indanthrene Scarlet 2G	Bleached Linen and Boiled Cotton Yarn	1·5% powder	Red
(distinct from Indanthrene Scarlet R which appears dark).			
Indigosol Yellow V (D. & H. & I.G.)	Bleached Linen and Boiled Cotton Yarn	3% powder	Bright Yellow

It is to be noted that the majority of yellow vat dyestuffs show a yellow to red fluorescence in some degree under the lamp as also do some of the oranges and reds and purples, but vat dyestuffs of other colours, viz. greens, blues, browns and blacks show comparatively little effect.

It is interesting to observe that in some cases the alkaline reduction or " leuco " compound of a vat dyestuff which does not itself exhibit appreciable fluorescence under the lamp, may show definite colours and vice versa. Indigo M.L.B. (20 per cent. paste dyeings on bleached linen and boiled cotton yarns) for example, appears dark under the lamp, whereas its yellow alkaline reduction compound fluoresces with a bright yellowish-green colour. Again, Algol Brilliant Green BK (15 per cent. paste dyeings on bleached linen and boiled cotton yarns) appears dark under the lamp whereas its alkaline reduction compound shows an orange-red fluorescence.

Indigosol Yellow HCG (HelindonYellow CG) shows little fluorescence under the lamp, but its alkaline reduction compound (also yellow) shows a yellow fluorescence. Indanthrene Yellow 7GK (3 per cent. powder on bleached linen yarn and boiled cotton yarn) shows a yellow fluorescence whereas its brownish-purple reduction compound appears dark.

A considerable number of direct dyestuffs show more or less brilliant fluorescence colours and the following table gives a selection of these.

It is to be noted, again, that fluorescence colours are shown by the yellow, orange, red and purple members and that with one or two apparently isolated exceptions the green,* blue, brown and black dyestuffs show little or no fluorescence under the lamp.

Figures 7A and 7B show two hanks of boiled cotton yarn one dyed with Brilliant Dianil Green G (0·5 per cent.) and the other with Sirius Supra Green 2B (0·5 per cent.). Figure 7A is a photograph of the two hanks in daylight and 7B a photograph taken under the lamp in a dark room. The Brilliant Dianil Green G dyeing shows a bright bluish-green fluorescence

* Brilliant Dianil Green G is stated to be a mixture of Brilliant Dianil Blue 6G with a Thiazol yellow.

(appearing white in the photograph) whereas the dyeing with Sirius Supra Green 2B appears dark.

Table V

Direct Dyestuffs which show distinct fluorescence colours under the lamp.

Dyestuff	Material on which sample tested was dyed	Depth of Dyeing	Fluorescence Colour
Direct Fast Yellow FF (S.C.I.)	Mercerised Cotton Yarn	0·2%	Yellow
Direct Fast Yellow B (S.C.I.)	Mercerised Cotton Yarn	0·2%	Yellow
Dianil Yellow 3G (I.G.)	Unbleached Cotton Yarn	2·0%	Yellow
Oxydiamine Yellow TZ (I.G.)	Unbleached Cotton Yarn	1·5%	Yellow
Thioflavine S (I.G.)	Unbleached Cotton Yarn	0·5%	Bright Yellow
Chlorazol Yellow 2GS (I.C.I.)	Bleached Cotton Yarn	0·35%	Bright Yellow
Chlorazol Yellow 6GS (I.C.I.)	Bleached Cotton Yarn	0·35%	Yellow
Chlorazol Yellow 8GS (I.C.I.)	Bleached Cotton Yarn	0·35%	Yellow
Primuline AS* (I.C.I.)	Bleached Cotton Yarn	5·0%	Bright Yellow
Primuline G* (I.C.I.)	Bleached Cotton Yarn	5·0%	Yellow
Chlorazol Orange-brown RS (I.C.I.)	Bleached Cotton Yarn	0·5%	Dull Yellow
Dianil Orange G (I.G.)	Unbleached Cotton Yarn	0·5%	Orange-red
Congo Red (I.C.I.)	Bleached Cotton Yarn	0·25%	Red
Benzopurpurin 10BS (I.C.I.)	Bleached Cotton Yarn	0·25%	Red
Benzo Fast Red GL (I.G.)	Unbleached Cotton Yarn	0·5%	Red
Oxamine Red X (I.G.)	Unbleached Cotton Yarn	0·5%	Red
Chlorazol Rose BS (I.C.I.)	Bleached Cotton Yarn	0·4%	Red
Chlorazol Pink YS (I.G.)	Bleached Cotton Yarn	0·4 %	Bright Red
Diamine Red 10B (I.G.)	Unbleached Cotton Yarn	0·5%	Violet
Chlorazol Fast Red 10B (I.C.I.)	Bleached Cotton Yarn	0·2%	Violet
Brilliant Dianil Green G (I.G.)	Unbleached Cotton Yarn	0·5%	Bright Bluish-green
Brilliant Benzo Violet R (I.G.)	Unbleached Cotton Yarn	0·4%	Bright Bluish-red
Chlorazol Violet RS (I.C.I.)	Bleached Cotton Yarn	0·4%	Bright Bluish-red
Sirius Supra Violet FFR (I.G.)	Unbleached Cotton Yarn	0·33%	Bright Bluish-red

* The dyeings produced on cotton by the diazotisation of Primulines AS and G and coupling with various bases show comparatively little fluorescence. The dyeing produced by coupling diazotised Primuline AS with β-Naphthol (Primuline Red) shows a dark red fluorescence. On splitting by boiling with Titanous Chloride solution, the residual Primuline on the fibre shows the characteristic yellow fluorescence.

A number of basic colours dyed on mordanted cotton (or linen) and on unmordanted wool or silk give characteristic fluorescence colours and a selection of these is given in Table VI.

Table VI

Basic Dyestuffs which show distinct fluorescence colours under the lamp.

Dyestuff	Material on which sample tested was dyed	Depth of Dyeing.	Fluorescence Colour
Acronol Yellow (I.C.I.)	Bleached Cotton Yarn mordanted with Tannin	0·5%	Greenish-yellow
Auracin G (I.G.)	Bleached Cotton Yarn mordanted with Katanol ON	0·25%	Greenish-yellow
Auramine OS (I.C.I.)	Bleached Cotton Yarn mordanted with Tannin	0·25 %	Yellow
Acridine Orange LPS (I.C.I.)	Bleached Cotton Yarn mordanted with Tannin	0·25 %	Orange-red
Acridine Orange RS (I.C.I.)	Bleached Cotton Yarn mordanted with Tannin	0·25%	Orange-yellow
Rhodamine BS (I.C.I.)	Wool Silk	0·3% 0·25%	Bright Orange-red
	Boiled Cotton mordanted with Tannin	0·1%	Dark Red
	Boiled Cotton mordanted with Katanol ON	0·1%	Darker Red
Rhodamine 6GBS (I.C.I.)	Wool Silk	0·3% 0·25%	Bright Orange-yellow
	Bleached Cotton mordanted with Tannin	0·25%	Dull Brownish-yellow
Astraphloxin FF (I.G.)	Bleached Cotton Yarn mordanted with Tannin	1·0%	Bluish-red.
Astra Violet FF (I.G.)	Bleached Cotton Yarn mordanted with Tannin	0·5%	Bright Bluish-red

A number of other yellow and orange basic dyestuffs on mordanted cotton or linen show fluorescence colours.

A number of acid dyestuffs also show definite fluorescence colours and a selection of these is given in Table VII.

Table VII

Acid Dyestuffs on Wool and Silk which show distinct fluorescence colours under the lamp.

Dyestuff	Material on which sample tested was dyed	Depth of Dyeing	Fluorescence Colour
Eosine (I.C.I.)	Wool Silk	0·3 % 0·25%	Brilliant Orange-yellow
Phloxine BS (I.C.I.)	Wool	0·3%	Red
Acid Magenta AS (I.C.I.)	Wool	0·4%	Bluish-red
Coomassie Violet RS (I.C.I.)	Wool	0·3%	Purple
Coomassie Violet 2RS (I.C.I.)	Wool	0·25%	Red

Fluorescence was also observed with a number of other yellow, orange, red, purple, green and blue acid dyestuffs on wool.

Table VIII gives a number of sulphur dyeings on cotton yarn which show fluorescence colours.

Table VIII

Sulphur Dyestuffs showing distinct fluorescence colours under the lamp.

Dyestuff	Material on which sample tested was dyed	Depth of Dyeing	Fluorescence Colour
Immedial Yellow 2G (I.G.)	Unbleached Cotton Yarn	2·0%	Bright Yellow
Thionol Yellow GRS (I.C.I.)	Bleached Cotton Yarn	3·0%	Yellow
Thionol Yellow RS (I.C.I.)	Bleached Cotton Yarn	2·0%	Yellow
Thionol Yellow GS (I.C.I.)	Bleached Cotton Yarn	4·0%	Yellow
Thionol Yellow YS (I.C.I.)	Bleached Cotton Yarn	4·0%	Yellow
Sulphur Yellow 4G (I.G.)	Unbleached Cotton Yarn	2·0%	Yellow
Sulphur Yellow R (I.G.)	Unbleached Cotton Yarn	1·0%	Yellow
Sulphur Yellow G (I.G.)	Unbleached Cotton Yarn	1·0%	Brownish-yellow
Thionol Orange RS (I.C.I.)	Bleached Cotton Yarn	2·0%	Yellowish-brown

It was observed that an after-treatment of these sulphur dyeings with copper-chrome reduced the fluorescence very considerably.

Of the cellulose acetate dyestuffs examined it was found that the following (Table IX) showed distinct fluorescence colours.

Table IX

Cellulose Acetate Dyestuffs showing distinct fluorescence colours under the lamp.

Dyestuff	Material on which sample tested was dyed	Depth of Dyeing	Fluorescence Colour
Celliton Brilliant Yellow FF (I.G.)	Cellulose Acetate Yarn	1·5%	Very brilliant Greenish-yellow
Duranol Brilliant Yellow 6G 300 (I.C.I.)	Cellulose Acetate Cloth	1·0%	Very brilliant Greenish-yellow
Celliton Fast Yellow 7G (I.G.) (distinct from Celliton Yell	Cellulose Acetate Yarn ow 5G which appears dark)	1·5%	Bright Yellowish-green
Celliton Fast Pink FF3B (I.G.)	Cellulose Acetate Yarn	2·0%	Red
Celliton Fast Pink RF	Cellulose Acetate Yarn	2·5%	Orange-red
Duranol Orange CS (I.C.I.)	Cellulose Acetate Yarn	10·0%	Orange-yellow
Duranol Orange GS (I.C.I.)	Cellulose Acetate Yarn	10·0%	Orange
Duranol Scarlet 2G (I.C.I.)	Cellulose Acetate Yarn	10·0%	Red
Duranol Scarlet B (I.C.I.	Cellulose Acetate Yarn	10·0%	Red
Duranol Scarlet 2BS (I.C.I.)	Cellulose Acetate Yarn	10·0%	Red
Duranol Scarlet 3B (I.C.I.)	Cellulose Acetate Yarn	10·0%	Red
Duranol Red X3BS (I.C.I.)	Cellulose Acetate Yarn	10·0%	Bright Red
Duranol Violet 2RS (I.C.I.)	Cellulose Acetate Yarn	5·0%	Red

Fluorescence of Alkaline Solutions of Naphthols (Brenthols)

Alkaline solutions of the naphthols (naphtholates) all show definite fluorescence colours under the lamp when spotted on to filter paper or fabric, whereas the dyeings (i.e. after coupling) show comparatively little fluorescence.

Samples of the Brenthols and Naphthols were dissolved in dilute caustic soda solution and the resulting solutions spotted on to No. 5 Whatman Filter paper and examined under the lamp. The results are shown in the following table :—

Table X

Fluorescence Colours of Alkaline Solution of Naphthols (Brenthols) after spotting on to filter paper.

Brenthol or Naphthol	Fluorescence Colour
Naphthol AS (Brenthol AS)	Bright Greenish-yellow
,, AS-BO (,, AN)	,,
,, AS-E (,, BB)	,,
,, AS-SW (,, BN)	,,
,, AS-TR (,, CT)	,,
,, AS-BR (,, DA)	,,
,, AS-BG (,, FC)	,,
,, AS-OL (,, FR)	,,
,, AS-SG (,, GB)	,,
,, AS-LT (,, MA)	,,
,, AS-D (,, OT)	,,
,, AS-RT (,, PA)	,
,, AS-SR (,, RB)	,,
,, AS-ITR	,,
,, AS-LC	,,
Ciba Naphthol RPH	,,
Naphthol RT	,,
Naphthol AS-L3G	Bright Greenish-blue
Naphthol AS-LG	Duller Greenish-yellow
β-Hydroxynaphthoic acid	Duller Greenish-yellow
Naphthol AS-BS (Brenthol MN)	Olive-green
,, AS-GR (,, NG)	Red-orange
,, AS-L4G	Bright reddish-blue
,, AS-G (Brenthol AT)	,,
β-Naphthol	,,
Naphthol AS-LB (Brenthol BT)	Bright Blue
Ciba Naphthol ST	,,
,, ,, SD	,,
,, ,, SB	,,
Naphthol AS-DB	Bright Sky-blue

Mecheels[8] based a method of identification of Naphthol dyeings on the fluorescence of the naphtholates. Since his paper was published, several naphthols have been placed on the market which yield fluorescence colours other than the greenish-yellow referred to by Mecheels (he mentions Naphthol AS-G as the only exception).

In one or two cases it was found possible in the course of the present work to characterise the naphthol used in a coupled dyeing by means of the fluorescence of the naphtholates. In the case of yellow combinations it was found possible to distinguish between dyeings produced with Naphthol AS-G and those with Naphthol AS-LG and AS-L3G.

A small portion of the dyed cloth was boiled in the following solution until reduced :—

30 g. Sodium Hydrosulphite.
120 c.c. Caustic Soda Solution, 62° Tw., to 1 litre with water.

The pattern was then squeezed between filter paper and examined under the lamp. Combinations with Naphthol AS-G gave the characteristic reddish-blue fluorescence whereas those with Naphthols AS-LG and AS-L3G gave the greenish-yellow colour.

Some interesting results were obtained with a number of brown dyeings produced with Naphthols AS-LB, AS-BR and AS-BG and it was found possible in the combinations tested to distinguish dyeings produced with Naphthol AS-LB from those with AS-BR and AS-BG.

The Naphthol AS-LB combinations gave a blue fluorescence after acid reduction in substance. The dyed sample was extracted with glacial acetic acid, the extract concentrated to a small volume and the colouring matter reduced by adding sodium hydrosulphite and boiling vigorously. The liquor was poured on to filter paper, washed rapidly in water and finally rinsed in caustic soda solution, 62° Tw.

The Naphthol AS-BR combinations tested gave a greenish-yellow fluorescence while those with AS-BG gave a yellowish fluorescence.

It was not found possible to obtain satisfactory fluorescent colours with brown combinations from Naphthol AS-DB nor with yellow combinations from Naphthol AS-L4G, owing possibly to decomposition of these naphthols under the reducing conditions employed.

Other Applications of the Lamp in the Examination of Dyed Materials.

1. It is often possible to determine whether dyeings of the same shade have been made with different dyestuffs.
2. The lamp is often of help in rendering visible small differences in depth of dyeing, more particularly in medium to pale shades.
3. Faded portions of a dyed cloth which has been exposed to light may be rendered more pronounced when examined under the lamp. This is of value when determining the distribution of the faded portions.

A recent application of ultra-violet radiation consists in the examination by means of a special apparatus made by the Hanau Quarzlampen-Gesellschaft, of material being printed with light coloured printing pastes, e.g. Rapidogens, which are subsequently to be developed. By the incorporation of suitable fluorescing substances in the printing paste, irregularities such as doctor marks, etc., may be detected and corrected while the machine is running.[4]

3. Fluorescent effects of Cellulose which has been subjected to the action of heat.

If a normally bleached linen or cotton cellulose is heated beyond a certain temperature, a bluish fluorescence is produced which is marked if the material is scorched.

Fort[5] has described a heat test applicable to linen and cotton materials for distinguishing qualitatively, between tendering due to the action of acids and to that of hypochlorites. He found that at temperatures of 150° C. and over, materials tendered with chemic turned brown more rapidly than similar materials tendered with acids. The effect is stated to be definite after the tendered materials have received a boil in caustic soda solution.

Experimental

Samples of bleached cotton and linen fabrics were tendered by treatment with warm neutral lime dip (2·8 g. available chlorine per litre) until appreciably tendered and other samples of the same fabrics were tendered to a similar extent (judged approximately by hand tearing tests) by boiling in 1 per cent. sulphuric acid solution.

The chemicked samples were antichlored by rinsing in ½ per cent. solution of sodium metabisulphite, washed and rinsed in a cold solution of very dilute ammonia and finally washed and dried.

The acid tendered samples were washed, rinsed in very dilute ammonia and finally washed and dried.

Samples of the fabrics after these treatments together with the original untreated samples were placed on a white tile and heated in an electric oven to 140-155° C. for three-quarters of an hour. The chemicked samples were brown while the acid treated samples and the original showed little change.

When examined under the lamp the browned samples showed a bright greenish-blue fluorescence whereas the other samples showed very little fluorescence. Comparatively little fluorescence was observed in any of the samples before heating.

The experiment was repeated giving both the tendered and the original samples a preliminary boil for 3½ hours in 2 per cent. caustic soda solution. The samples were then washed, soured, washed in dilute ammonia solution and finally washed and dried. On heating to 170-175° C., a marked fluorescence was observed with the chemicked samples, a slight fluorescence only being observed with the others.

4. Examination of miscellaneous materials.

Metallic Soaps.

A sample of calcium soap was prepared by precipitating a hot 1 per cent. solution of Textile Flake soap with an excess of calcium chloride solution, filtering and washing. After smearing a portion on to bleached cotton and bleached linen cloth (as used throughout this work) a pale greenish-yellow fluorescence was visible. A subsequent souring treatment with dilute acetic acid solution showed a slight enhancement of the fluorescence.

A sample of Iron Oleate smeared on to the bleached fabrics appeared very dark under the lamp. On removing the bulk of the iron by treating the smeared fabrics with warm 5 per cent. oxalic acid solution, the residual fatty acid showed a bright yellow fluorescence.

Examination under the lamp may be of help in providing additional evidence in the examination of stains suspected to be due to contamination with metallic soaps.

Fluorescence of Moulds, Bacteria, etc.

Some, though not all, mildew stains on fabrics show fluorescent effects in ultra-violet light, and examination under the lamp may sometimes be useful in determining the distribution of the mildew. Figure 8 shows a sample of a finished linen sheeting photographed in ultra-violet light. It was submitted for report on the staining in the neighbourhood of the selvedge. The lamp shows a number of fluorescent spots or spots surrounded by fluorescent material, in association with a tide-mark which is clearly visible in the photograph. The spots were shown microscopically to be due to

mildew and it was concluded that a bolt of cloth became wetted at the selvedge and that the mildewing developed while in storage.

CONCLUSIONS

The effects obtained with the lamp described show that the results cannot be regarded necessarily as specific but, especially as they may in general be obtained without mutilation of the sample under examination, these results are often valuable as evidence auxiliary to that provided by other methods of test.

SUMMARY

1. A portable ultra-violet lamp is described suitable for the examination and testing of textile materials.
2. Some of its applications are discussed in connection with the examination of oils and oil stains and of dyed materials.
3. Its use in a number of other cases is also referred to.

The author's thanks are due to Mr. C. R. Nodder for several suggestions and to Messrs. The Thermal Syndicate Ltd., Wallsend, Northumberland, for their interest in the production of the lamp.

In conclusion the author is indebted to the Council of the Linen Industry Research Association for permission to publish this work.

REFERENCES

[1] Judd Lewis, *J. Soc. Dy. Col. Bradford*, 1922, **38**, 68.
[2] Radley and Grant, " Fluorescence Analysis in Ultra-Violet Light." Chapman and Hall, 1933, page 86.
[3] Mecheels. *Textilber.*, 1931, XII, 9, 581.
[4] I. G. Farbenindustrie, Höchst, Textilber., 1937, XVIII, 4, 310.
[5] Fort, *J. Soc. Dy. Col. Bradford*, 1932, **48**, 94.

Received 17/3/37.

10—A SPINNING PROCEDURE FOR COTTON SAMPLES

By H. A. HANCOCK, B.Sc.
(Spinning Technologist to the Ministry of Agriculture, Egypt)

SUMMARY

(1) The technique employed in the Spinning-Test Mill at Giza (Egypt) is described.

(2) The standard error of a spinning-test under conditions specified is shown to be about 1 per cent.

(3) In comparing the spinning values of old or new varieties, the strength level to which the yarns are spun is found to be of little consequence. Providing the cottons are given identical treatment, they rank in much the same order whether spun from combed or from carded preparation, in fine or in coarse counts, in warp twist or in doubling weft, over the range of Egyptian cottons. A spinning in a medium counts carded yarn gives sufficiently accurate information for most purposes.

(4) The cash value of a cotton sample may be estimated from the result of its spinning-test.

The conduct of spinning-tests using standard industrial machinery has been fully described by Balls[1] in his "Handbook of Spinning-Tests for Cotton Growers"; and in 1920, when that was written, there was no research installation in existence which had been set up for the especial purpose of testing growers' samples. Since that time several experimental spinning plants have come into being either wholly or partly for the purpose, of which the most recent is the Spinning-Test Station at Giza, attached to the Botanical Section of the Egyptian Ministry of Agriculture. Although primarily concerned in the search for new Egyptian varieties which shall be more acceptable than the old varieties both to grower and to spinner, the new venture is found to be wider in its scope than had originally been hoped; and progress has already been made in several fundamental problems of growing, marketing and spinning, with useful practical applications.

To spinners, a spinning-test is an experiment in spinning in which variable factors may relate to the technique, machines, or the material passing through. To cotton breeders, however, the term is generally understood to mean a small-scale spinning in which the essential variant is the cotton. The aim of the present discussion is to describe the technique developed at Giza, showing how the spinning factors are standardised so that the result of a spinning-test is as far as possible an expression of the cotton properties only; in so doing, several points of interest to spinners and to cotton breeders arise, and the account forms a basis of reference for experimental results in future publications.

In order to overcome the difficulties peculiar to the spinning of small samples, a few modifications of normal technique become necessary or desirable ; but it has been ensured that these are not of such a nature as to upset the general parallelism between the test results and those of industrial practice. Fortunately, it is found that with Egyptian cotton very wide latitude is permissible in the strength level to which yarns are spun, without change in *relative* values, even when the varieties compared are widely different.

Until comparatively recently, the three major errors of a spinning-test could be stated as those due to faulty sampling, to excessive absorption of small samples by the card clothing, and to incorrect roller settings. Modern technical advances have enabled two of these errors to be reduced to negligible proportions ; but the errors of sampling are liable to remain, and they increase in importance as the size of the sample is reduced.

It can hardly be over-emphasised that the accuracy of a spinning-test depends on the adequacy of the sampling, and the essential principle to be observed is that the cotton under test must be abstracted from all parts of the bulk it represents. The difficult subject of sampling will be discussed later when considering the probable error of spinning-tests ; for the moment it need only be mentioned that this error can usually be reduced to unimportance by dividing the bulk into twenty parts and sampling from each part. Although only one kilogram ($2\frac{1}{4}$ lbs.) of cotton is used for a standard spinning-test in our field experiments at Giza, this amount may be made fully representative of a bulk of 100 lbs. or more.

Spinning Technique

The kilogram of cotton presented for a spinning test is hand-fed direct to the card—a weighed amount at every revolution of the feed roller—without any previous cleaning. For samples of this small size, openers, scutchers, etc., are superfluous. With a little practice, the cotton can be laid quite evenly on the card feed-plate, and slivers of fairly uniform weight are obtained. In order to compensate for the total lack of blow-room cleaning, after first card the sliver is wound on to a drum forming a sheet of about 80 ends, which is rolled up into a lap and carded a second time ; this lap is weighed and brought to correct weight by removing an appropriate number of ends as it unrolls at second card. The hank of sliver is thus accurately controlled and the web is more than usually clean. Mixings, if required, may conveniently be made at this sliver lap stage, the proportions of the components being determined by the relative number of ends in the lap.

A carding engine clothed with Roubaix (Metallic) wire on cylinder, doffer, and flats, is positively a necessity for standardised spinning-tests on small samples. Its chief advantages are (*a*) that there is no loss of cotton in the form of cylinder and doffer strippings, for the wire never fills up and is therefore never stripped ; (*b*) the carding action is the same at the beginning of the sample as at the end, and there is not that selective absorption of neps, etc., to an extent dependent on the cleanliness of the wire, from which ordinary wire suffers[2] ; and lastly, (*c*) Roubaix wire clothing needs re-grinding at intervals so long as to be measured in years, entailing longer periods between re-settings and greater constancy of the machine altogether. It may usefully be mentioned here that the closeness of the doffer to cylinder setting is of great importance for high quality

cottons; a wide setting tends to produce cloudy and neppy webs, and a setting of five thousandths of an inch is recommended.

After every sample, the taker-in waste is collected and weighed, the percentage amount having been found a fairly reliable index to grade. The weight of the flat strips is roughly constant for all varieties of cotton.

A revolution counter actuated by the doffer measures off the second card sliver into eight equal lengths ready for drawings. A five-delivery draw-frame is used with the drawing rollers set slightly out of parallel—all converging towards the gearing end—in order to avoid the necessity for frequent changes in roller settings. Thus the first delivery has settings appropriate for Ashmouni staple, the second delivery for Giza 3, the third for Giza 7, the fourth for Sakel, and the fifth delivery for super-long staples such as Sakha 4 or Maarad. The slight convergence necessary—about half-an-inch over the whole length of the frame—is easily accommodated both by the roller bearings and the gearing. Samples are given three drawings, and usually wrap to within a half of 1 per cent. of correct hank at the final drawing; to attain to this accuracy precautions must be taken to avoid stretching of the sliver between drawings, and the standard sliver guide behind the draw-frame needs to be modified.

So far the samples have been given individual treatment, but at the slubber they are assembled into groups of twelve, and henceforward all members of the group are treated identically and simultaneously. In general, a group is composed of samples of approximately similar type, but this is not always the case and provision therefore has to be made to accommodate different staple lengths passing through the drafting rollers of adjacent spindles. To this end Casablancas' drafting system, working at the low draft of five, is fitted on all the speed frames; this system has the faculty of dealing with both long and medium staples under nearly optimum conditions without change of roller setting. On these frames Ashmouni and Maarad cottons may be seen drafting alongside each other perfectly satisfactorily, at a roller setting which has remained unaltered for all our cottons since the initial experiments in which settings were determined. Cork cots are fitted to all top rollers, as they are found to have a more permanently constant surface than varnished leather.

Four slubber bobbins, each from a different spindle, and similarly four intermediate and four roving bobbins, are produced per sample. In order to economise in space, spares, and bobbins, the slubbing frame is also utilised as an intermediate frame, being fitted with a bobbin creel and a compound gear in the twist system for the dual purpose; from 2 to 7 hank roving can be dealt with, and the change-over takes about ten minutes. A similar compound gear is fitted in the twist system of the rover, which can produce any roving between 7 and 20 hank wrappings. Between processes, the bobbins (numbered 1 to 12) are pegged on to boards, the spacing being equal to the spindle staff; this minimises the chances of a bobbin being displaced out of correct order, and keeps the members of each group together. At every creeling the man in charge of the machine checks up the feed bobbin numbers with the delivery bobbin numbers, and an independent check is then made by a second man who is detailed to supervise every creeling in the mill. Probably the best chance for confusion of samples arises at the frame-room creelings; particularly is this so at the slubber, where the labels on the cans cannot be seen from the front of the machine.

At the ring frame all the twelve samples of a group are spun simultaneously, occupying 12 spindles; twelve doffings are made, each sample moving along to the next spindle after every doffing, so that after twelve doffings every sample has been on every spindle, which procedure eliminates the spindle error inside a group. At the sixth doffing, each pair of roving bobbins in the creel is replaced by the other pair of the same sample; testings of the yarn from the two pairs are done separately and must agree before the result for the sample is accepted. Although the variance between roving bobbin pairs is small—on purely statistical grounds the duplication is perhaps unjustified—the two independent values are useful if only as a check against mistakes.

The ring frame has a headstock at each frame-end, and is divided into four sections each with independent draft gearing, so that four groups can be spun simultaneously. Repeated checks have shown that all four sections are equal within very close limits, and it is a matter of indifference on which section any group is spun. Casablancas' drafting system is fitted to each section.

It may be thought that the routine described, involving so many doffings and re-creelings on all the frames, is too tedious to be practicable; but actually, as spinning-tests go, the rate of working is very fast. The mill was cleared for action at the beginning of September, 1936, during which month 300 samples of the new crop arrived. By the end of November all these samples had been spun, representing an out-put of one sample every 86 minutes of working time; and in addition 96 of the samples were spun again in two extra twist factors and doubled into two-folds during the period, the staff engaged on the machines being four men and three boys.

Table I
Details of Hank Numbers and Drafts
(All cottons treated the same)

Machine	Number of ends up	Draft	Twist Factor	Hank Produced
1st Card	—	98	—	0·20
2nd Card	75-80	98	—	0·26
Drawframe	8	8	—	0·26 (3 drawings
Slubber	1	5·0	0·70	1·30
Intermediate	2	5·0	0·82	3·25
Rover	2	5·0	0·88	8·12
Ring	2	14·7	3·6	60

(Ring spindle speed 8,000 r.p.m., tape drive; $1\frac{3}{8}''$ rings building on to parallel-sided wooden bobbins, $\frac{7}{8}''$ diam.)

Staple Measurements

Although they are not strictly part of a spinning-test, it is usual to report measurements of staple length and hair-weight along with the yarn tests, and for the purpose of reference the methods used at Giza are given here. The test material is always a length of third draw-frame sliver; for the purpose of correlating yarn and staple characters, the sampling is thus ensured to be above reproach.

Staple length is measured by the Balls Sorter,[8] which is found to be quicker and more accurate than the Baer Sorter; the apparatus gives

a diagram showing the proportion of cotton *by weight* as shown in Fig. 1. From this diagram a quantity named the " half-fall " is measured off which agrees closely with staple length as estimated by graders.

To estimate the half-fall, a perpendicular is dropped from the sorter peak B (Fig. 1) to A ; a horizontal is drawn through C (AC equals ½ AB) intersecting the curve at D ; a perpendicular is dropped from D to E, and the length OE is defined as the half-fall. The fact that this value agrees with the graders' staple length is the only justification for the construction. The half-fall is actually designated as staple length in our publications, expressed in thirty-secondths of an inch as being more suitable for rapid comparisons ; for Egyptian cottons the value so obtained also agrees closely with the " effective length " measurement of staple, derived from the Baer Staple Diagram.[4]

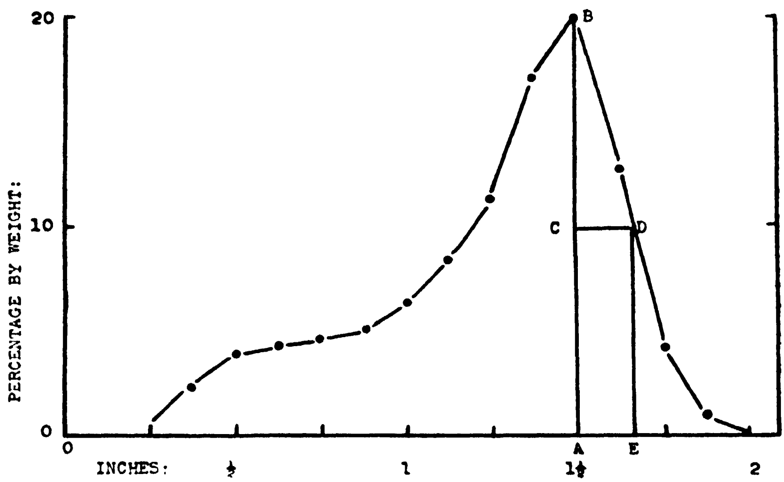


FIG. 1. Geometrical construction for the " half-fall " measurement of staple length from the Balls Sorter Diagram.

The hair-weight, which is a measure of staple fineness, is determined by counting the number of hairs laid out on a slide under a microscope, cutting the assembled bundle to a known length, and weighing on an assay balance. Knowing the total number of centimeters and the weight, the average weight of a centimeter of hair, which is the hair-weight, may then be calculated. The value is expressed as a three-figure number, the omission of ·00 mgm./cm. being understood.

Counts Corrections

Twenty-four leas are tested per sample and, according to universal practice, yarn strength is presented as the product of lea strenth × counts, shortly known as the " lea product ". This figure is equivalent to strength per unit weight, since count varies as the reciprocal of weight, and it corrects for small differences berween the actual and the nominal counts when comparing values. Constant product at variable counts is implied by its use, but actually the product falls as the counts are raised, and the correction applies only to small deviations from the nominal.

Under the conditions of spinning-test work a further correction is necessary because fairly large counts variations are liable to arise. When draw-frame slivers of equal hank but different cottons are passed together (or separately) through slubber, intermediate, rover and ring frame, even though they are given simultaneous identical treatment, they do not all arrive at the same final counts. This phenomenon of the effective draft-constant of machines varying according to the cotton is known in the industry[5] and is dealt with, if necessary, by alteration of the draft at subsequent machines. In the case of our test groups the different cottons go through together, and although we can maintain the average counts at correct value, the extreme samples in the group may vary widely—strong yarns run coarse, weak yarns run fine. With the same draft wheels in each case, it is possible for an Uppers cotton to be wrapping 65's, whereas a Sakel spinning alongside may be wrapping 55's. In general, occasion does not arise to compare such extreme samples and they rarely occur in the same group; nevertheless the deviations are always present to some degree, and accuracy is improved by corrections to the lea product according to the counts level. By this means deviations as high as ten counts units could be satisfactorily corrected should they arise in exceptional cases.

The data for corrections are obtained simply by spinning type yarns a few numbers finer and a few numbers coarser than the nominal counts, keeping the turns per inch constant. The detailed corrections hardly merit full presentation, being characteristic merely of our particular conditions; a correction of 40 units to the lea product for every unit deviation from nominal 60's (added if finer, subtracted if coarser) is accurate enough for most purposes, over the range of Egyptian cottons. At softer twists the correction is greater, particularly if the counts are on the fine side. These corrections are made to all lea products quoted in our publications; a somewhat similar method is recommended by the U.S. Department of Agriculture.[6]

Accuracy of a Spinning-Test

It is essential to recognise that the yarn strength level as indicated by the lea product depends very largely on the spinning technique employed; it is only comparisons made under identical spinning conditions that matter. Using the same cotton, spinning to a constant counts and twist, different mills may obtain strength figures as much as 10-15 per cent. higher or lower than the average mill, and there is no figure generally acknowledged as a strength standard for the different varieties of cotton. Strength figures should never be compared between yarns from different mills because of this risk of a scale difference, and commercial comparisons with any claim to accuracy are usually possible only between yarns actually spun together.

In this our Spinning-Test Mill, the essential comparisons are made between the twelve cottons spun as a group, and all possible precautions are taken to ensure that any differences found are due to the cotton, and only to the cotton. There is, however, a possible source of large error which arises before the cotton ever enters the mill—the sampling error; no matter how accurate the spinning technique may be, results are of little value if the sample under test is not representative. That the variance due to sampling can be reduced to almost negligible importance when care is taken is shown by the consistency of repeat tests on samples grown in

different localities; these tests comprise all possible sources of variance, and yet the correlation coefficient between repeats may be as high as 0·99. The moral to be drawn is that in sampling any bulk it is sound practice to divide it into about twenty parts, and to abstract a little from each part in making up the sample; this expenditure of effort is very small compared to that subsequently expended on the sample in all the processes of a spinning-test. Similar care should be taken in halving a sample—each of the twenty lots should be halved separately. The balancing out of errors by suitable arrangement of experiments is too wide a subject to be dealt with here, but it is usually found that a little forethought before a new experiment begins is well repaid by the greater accuracy of results; the chequer or latin square principle of averaging-out can often be incorporated to advantage in some form or other. Tippet's[7] "Methods of Statistics" has valuable hints on the subject.

Inside the mill, most of the sources of variance are balanced out by the procedure described above, especially as regards spindle* errors. The largest of these is that due to the variance of ring spindles, the standard deviation of lea strength between spindles (cotton differences eliminated) being as high as 3 per cent.; the balancing out of this variance, as by

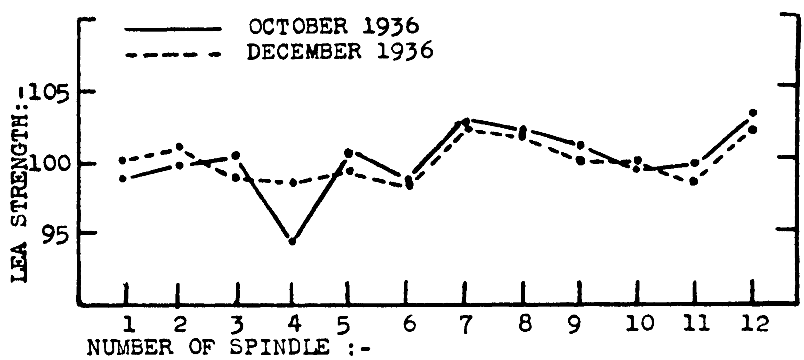


FIG. 2. Variation in lea strength of yarn spun on different ring spindles; the same spindles were producing strong or weak yarn in October as in December, except No. 4 spindle. The best spindle produced yarn 9 per cent. stronger than the worst spindle.

spinning each of the twelve samples on the same set of spindles, is essential for accurate work. These ring spindle differences, it may be mentioned, repeat fairly consistently over long periods of time (see Fig. 2); their study reveals many points of interest and will be discussed in a future publication.

On the other hand the variance of lea strength as between roving bobbin pairs is found to be very small, the lea strength irregularity between bobbins is about equal to the irregularity within the bobbins. In other words, the speed frame spindles are not found to transmit variable characteristics of their own to the cotton passing through them, so that multiple sampling of these spindles is of secondary importance, and there is no need to make a large number of roving bobbins.

A good estimate of the standard deviation of a spinning-test in 60's (comparing only the samples within a group), may be found from the analysis

* The term "spindle" in this connection includes drafting rollers, flyers, rings, etc., in line with the spindle.

of lea products from roving bobbin pairs, two independent pairs of which are averaged to give the mean of each spinning-test. The average difference (range) between one pair and the other of a sample is found to be 39 units of lea product; the standard deviation of the mean product of a bobbin

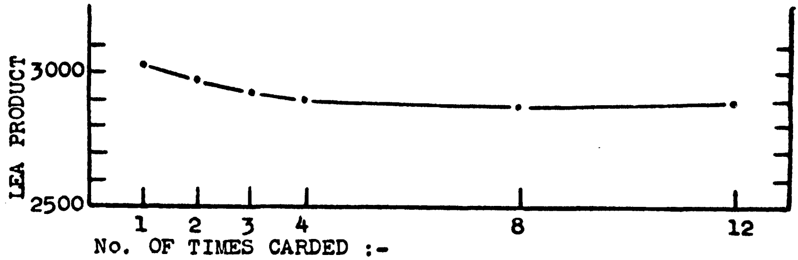


FIG. 3. The change in yarn strength (60's carded) of FG Sakel repeatedly carded; the evenness of the points along the curve illustrates the accuracy attainable in spinning-tests.

pair is thus[8] 35 lea product units, or 1·4 per cent. of the average product; and the standard deviation of the complete spinning-test is 1·0 per cent. Expressed in terms of ranges, this result means that the same cotton repeated ten times in a group would be expected to give strength values ranging from $101\frac{1}{2}$ to $98\frac{1}{2}$, the mean value being 100; or, the mean product being 2500, the range would be from 2535 to 2465. Under these circumstances

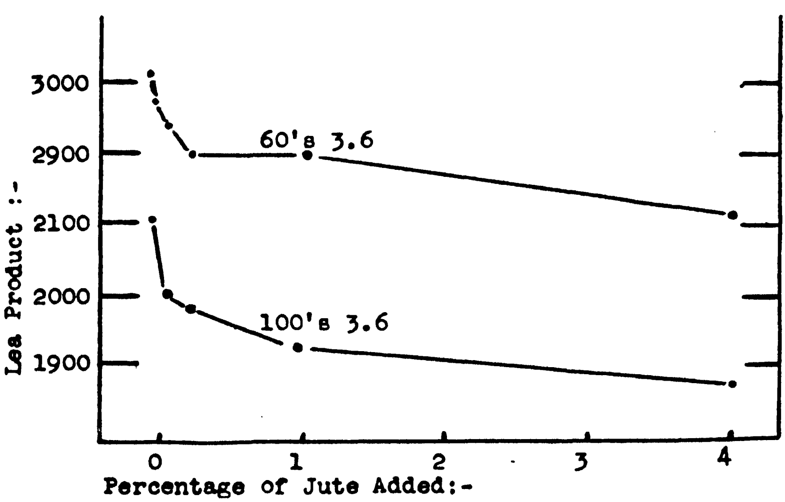


FIG. 4. Change in yarn strength when jute fibres are deliberately added to FG Sakel. (A half of 1 per cent. of jute represents the whole of a bale cover mixed in with a bale.) Illustrates the accuracy attainable in spinning-tests.

(according to statistical theory), a difference of 70 lea product units is indicative of a real difference between two samples nineteen times out of twenty; a difference of only 40 units is likely to be real nine times out of ten. To those unfamiliar with statistical methods of judging degree of acc uracy, the spinnings shown in Figs. 3 and 4 may be of help; these are series of cottons progressively changing in strength by small amounts. It will be noticed how smoothly the experimental points lie along the curves—

a most improbable occurrence if the errors of spinning were large compared to the real differences.

Less information is available to estimate the significance of differences between samples spun in different groups or at different times. Our spinnings are broadly divided into two seasons, from October to March, and from April to September ; inside a season, results from any groups appear to be comparable to nearly the same accuracy as within a group. This indeed ought to be the case, for everything humanly possible (within the limitations of our present knowledge) is done to maintain rigidly standard conditions ; the Roubaix-wire clothed card practically never needs re-grinding or re-setting and is almost invariable ; the cork-covered rollers on every frame from drawframe to ring frame present a far more constant surface than do leather rollers varnished to various degrees of efficiency ; roller settings are never changed on any frame whatsoever, and there is no error due to re-setting ; and above all, the building is almost extravagantly heat-insulated from outside conditions and its humidity is controlled by an efficient air

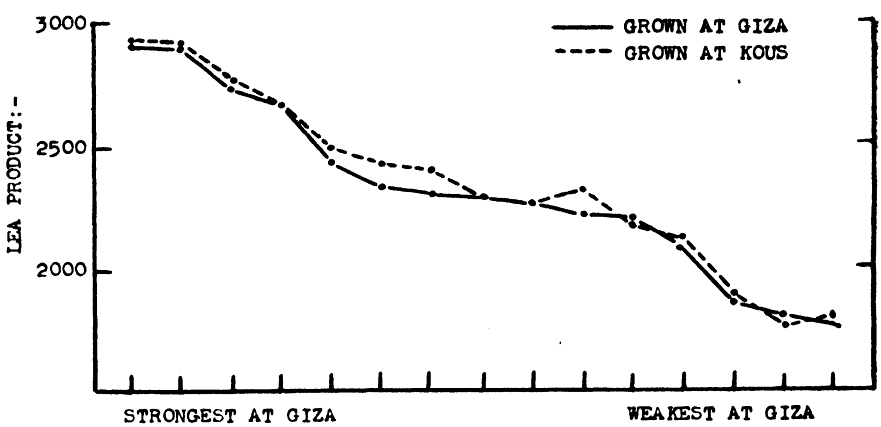


FIG. 5. Yarn strengths (60's carded) of 15 cottons grown in two localities. The samples are arranged (*l.* to *r.*) in descending order of strength at Giza. These comparisons involve all possible sources of error in a spinning test.

conditioning plant. The degree to which spinnings in different groups are comparable is indicated in Fig. 5, which shows the strengths of a series of cottons grown in two widely different localities. The deviations between the two curves comprise (*a*) the real differences between the cottons in the two localities, (*b*) any errors in the seed sampling or the growing conditions, (*c*) the errors of sampling of the lint, and (*d*) all the errors of spinning, for the samples were distributed over half-a-dozen groups spun during the course of several weeks. Hardly a sample is out of line in the two series, a remarkable agreement considering all the possibilities of variance.

A word or two on the humidifying plant may not be out of place here, for its importance in spinning-test work, whether at home or in sub-tropical climates such as Egypt, could hardly be overstressed. The particular plant in use (supplied by Messrs. Carrier of London) works on the principle of a constant dew-point in the humidifying chamber, stabilised by constant temperature of the re-circulated spray-water. When the outside wet-bulb

falls, the spray-water is heated by automatic control from a steam coil, and the heating process may be assisted by re-circulating the warm air in the building. Steam heated radiators in the ducts to all rooms dry down the saturated air to the required humidity, the steam supply to the radiators being controlled automatically from each room. The room-controls also regulate dampers in the ducts, admitting larger volumes of saturated air when the room humidity is too low. This plant maintains the relative

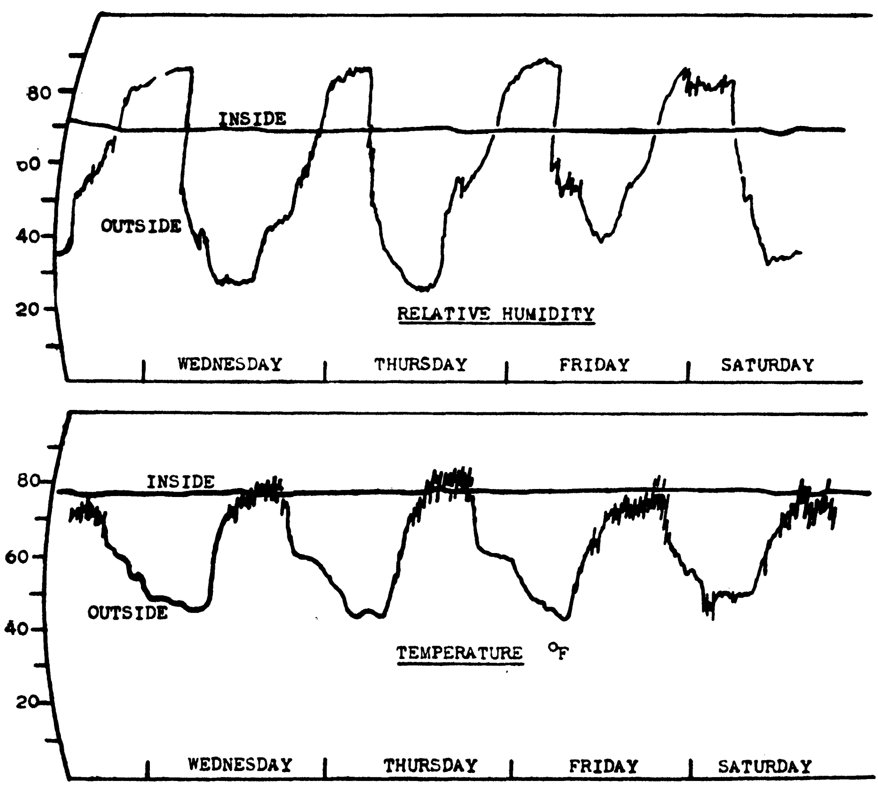


FIG. 6. Temperature and humidity inside and outside the mill in February, 1937. Friday was a holiday and the building was shut down, but the insulation of the building eliminated outside variations ; on the other days the air was being replaced at the rate of ten times the room volume per hour.

humidity in all the controlled rooms to within two or three per cent., day in, day out, all the year round, at 70 per cent. r.h. ; the record of Fig. 6, showing the inside and outside conditions in early spring, speaks for its efficiency better than any words of mine can do. The mill is run under two seasonal conditions, chiefly for economy in running costs ; the seasonal temperature variation in Egypt is exceptionally large—screened thermometer maxima range from 116° F. in summer down to 50° F. on exceptional days in winter. Although the heat-insulation of the building is amply capable of smoothing out the diurnal temperature variations, it cannot cut out the seasonal swings, and to maintain a constant indoor temperature all the year round would require either excessive fuel consumption in winter to overcome heat-losses, or equally expensive refrigeration in summer to overcome the

heat-gains. A winter indoor temperature of about 75° F., and a summer temperature of about 85° F., is maintained without excessive power costs either way. The difference in temperature probably influences yarn strengths but no opportunity has yet arisen to compare conditions, for the class of work during winter is usually unrelated to that done in summer.

Choice of Counts in Spinning-Tests

When an ordinary mill tests out a new cotton with the intention of its replacing a variety already in use, there is usually no difficulty in deciding what the counts in the spinning-test shall be—obviously the comparison would be made in the counts wherein its substitution is contemplated.

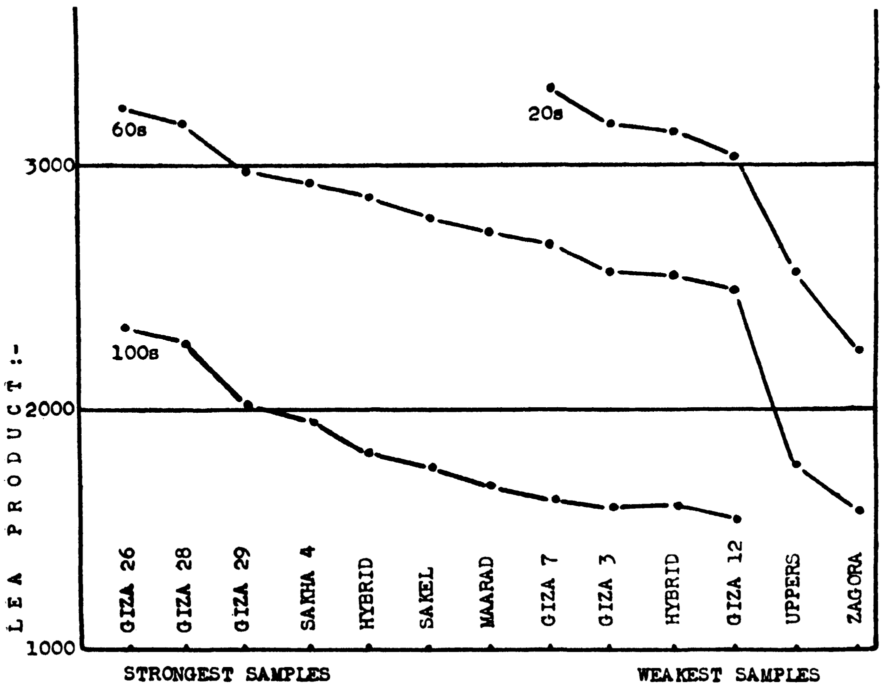


FIG. 7. Thirteen varieties of cotton spun in 2 or 3 carded counts ; each point is the mean of many samples of each variety. The cottons are seen to rank in the same order at whatever counts they are spun.

In our more general case, since the use to which any cotton might be put to in different mills is subject to wide latitude, the question arises, would the same answer be obtained when testing to fine counts as when testing in course ?

As is well known, the strength level is lower at finer counts, but from several hundred spinnings it is found that the order of ranking of any Egyptian variety is substantially unchanged whatever the counts at which the test is conducted (Fig. 7). This result is arrived at from consideration of the average behaviour of many samples of each variety, and does not imply that the individual samples do not vary ; on the contrary fairly large deviations sometimes arise between spinnings of individual samples in different counts. This is to some extent inevitable, since the error of a

solitary spinning is of course much higher than that of the summaries considered in the graph ; but the occurrence of relatively weak 100's associated with staple that is abnormally short or coarse appears to be more than a coincidence, and such cottons are often found to be relatively stronger in 20's. The primary interest is however in the behaviour of varieties as a whole, for the peculiarities of individuals must as a rule be toned down in commerce by the wholesale mixing of deliveries by ginner, merchant and spinner.

A standard counts—60's being chosen as a happy medium for Egyptian cottons—has therefore been adopted for all spinning-tests done at Giza, and any discussion refers to tests in this count unless it is stated to the contrary. The standardisation of technique amounting almost to mass production which followed on this valuable result enables a thousand samples a year to be dealt with easily, besides leaving time for miscellaneous researches.

It has also been satisfactorily established that tests on the carded yarns spun at Giza give parallel results to those on combed yarns spun elsewhere. Figure 8 shows the strengths of a series of cottons spun at Manchester into two combed counts (20 per cent. combed in all cases) each in two twist factors, and identical samples spun into two carded counts, 3·6 t.f., at Giza. Taking the average of the six spinnings as being the correct evaluation of the samples, it is seen that the 60's carded spinning places practically all

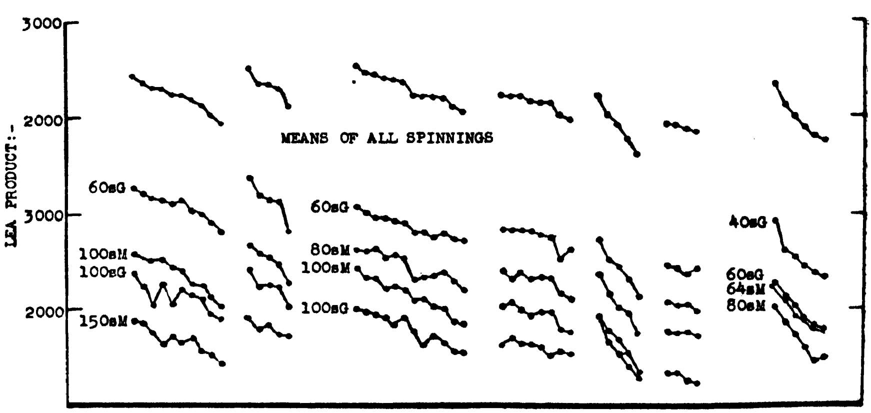


FIG. 8. Fifty cottons, covering the whole Egyptian range, spun in many counts. The cottons are divided into groups according to locality grown, and arranged from *l.* to *r.* in descending strength order inside each group. Each sample was spun in two CARDED counts, 3·6 t.f. at Giza (indicated by letter G), and in two COMBED counts at Manchester (indicated by letter M) ; the Manchester yarns were spun at 3·0 and 3·5 twist factors, and the value shown is the mean of these two spinnings. The cottons are placed in much the same order whatever the counts, and whether carded or combed, apart from random errors.

the samples in the correct order in each group. Various spinner friends in Europe have from time to time conducted tests for us, both carded and combed, on a mill scale, and these results also show good agreement with the carded spinnings done at Giza. There appears to be little point in introducing the extra complication of combing to spinning-test work. On the other hand, spinners dislike cottons which produce high comber waste at standard settings, and—regarded purely as a waste tester—the comber

has a place in our mill in order to ensure that wasty cottons are not among those selected for universal propagation.

It may be of interest to record that even at the very low strength levels produced by extreme yarn irregularity in freak spinning, the ranking order of varieties is largely unchanged. Yarns were spun using two machines only—the card and Casablancas' compound draft ring frame—whereupon the lea product fell to less than one half of the normal value, probably due to lack of parallelisation in the card sliver presented to the draft system (working at 300 of a draft) and to lack of doublings. But all varieties tested fell by roughly proportional amounts. The compound draft principle is not found satisfactory under the peculiar conditions of spinning-test work, with different cottons running side by side. The ribbon of cotton passing from one draft system to the other is condensed by passing it through a revolving tube—the false twist tube—and the strength of the yarn is governed partly by the amount of false twist; varieties differ rather widely in the requisite amount of false twist to give maximum strength, and since the false twist cannot be varied except for the frame side as a whole, samples are subject to a large, purely machine factor. This objection of course in no way applies to the commercial application of this very interesting machine.

Choice of Twist in Spinning-Tests

The twist factor at which test yarns are spun has some influence on *relative* strength values, apart from the change in the strength level as a whole; as noted by Morton,[9] cottons of low hair weight are found to be relatively stronger at soft twist.

When the twist factor is reduced as low as 2·0, the influence of the increased clinging power (arising from the larger number of hairs in the section) with low hairweight cottons may completely upset the yarn strength order found in the same cottons spun at 3·6 twist factor; but at the usual commercial limit for soft yarns, namely a 2·75 twist factor, the deviations from twist-yarn strength order are much reduced (Fig. 9). Greater length of staple tends to have an effect similar to that of low hairweight in raising the soft-twist strength, but of small magnitude over the usual range of twist factors. In practical comparisons of cottons appropriate to a given class of yarn, the range in hairweight or staple length will rarely be sufficient to cause a change in relative values according to the twist factor used. The influence of twist when the grade varies is excluded from the present discussion.

The Estimation of a Sample's Cash Value from its Yarn Strength

Cotton breeders have adopted the lea product yard-stick as a measure of quality simply because it is the criterion of spinners; it is sound business policy to supply what your customer demands. The justification of this policy is strikingly demonstrated by plotting the lea product of the Egyptian commercial varieties against their market prices, when all the points are found to fall closely along a straight line; a discussion on this result and its qualifications will be found in another publication.[10] The point of importance here is that spinners pay for strength and for little else, so that when the lea product of a new variety is known, its market value relative to familiar varieties may be read off without the cotton ever having been put on the market. Having arrived at this answer, the spinning-test may be regarded as completed.

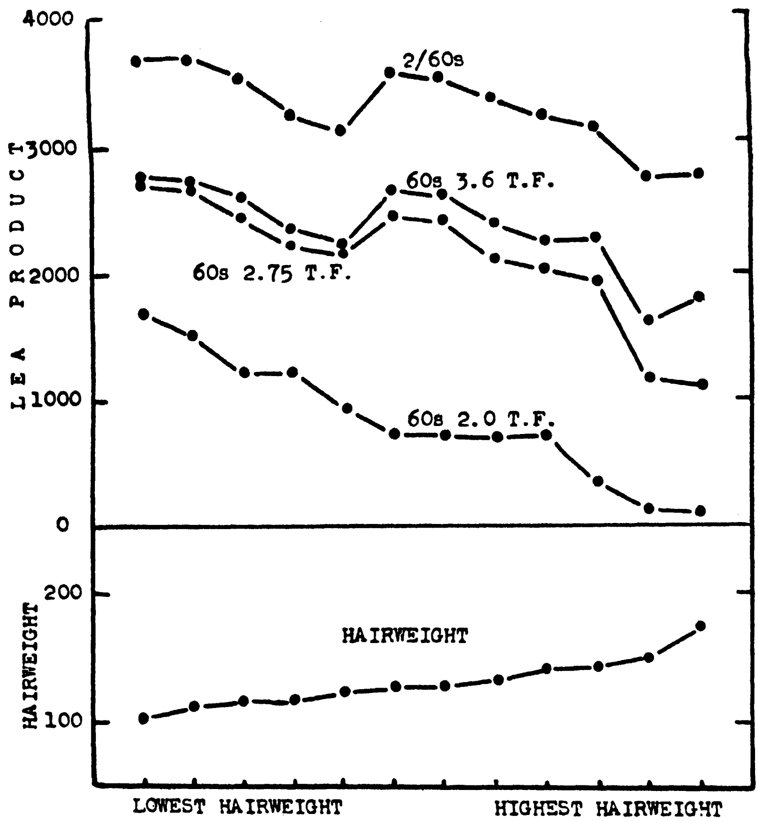


FIG. 9. Yarn strength at different twist factors. Twelve varieties of cotton are arranged (*l.* to *r.*) in order of ascending hairweight; the 2·75 t.f. and 3·6 t.f. curves diverge as the hairweight increases, coarse cottons being much weaker in doubling weft than in twist yarn. Each point is the mean of several spinnings.

It is with more than ordinary pleasure that I acknowledge the invaluable co-operation offered by Dr. W. L. Balls, F.R.S., at all stages in the development of the Spinning-Test Mill. I am also deeply indebted to my Chief of Department, Dr. James Templeton, whose able management abolished administrative and financial hitches as fast as they arose. To my chief assistants, Mr. Frank Dunkerley, Ahmed Yousseff Eff., and Hussein Shawky Eff., my thanks are due for skilled and enthusiastic services far in excess of their official duties.

REFERENCES

[1] Balls, W. L. Handbook of Spinning-Tests for Cotton Growers. Macmillan & Co., London, 1920.
[2] Turner, A. J. Technological Reports on Standard Indian Cottons, 1923-7, p. 19.
[3] Balls, W. L. A Method for Measuring the Length of Cotton Hairs. Macmillan & Co., London, 1921.
[4] Clegg, G. C. The Stapling of Cottons. *Shirley Inst. Mem.*, Series A, Vol. III, No. 2.
[5] Kidd, E. Lecture reported in *Textile Weekly*, p. 420, Oct., 1936.
[6] Campbell, M. E. An Improved Method for Converting an Observed Skein Strength to the Strength of a Specified Yarn Count. *U.S. Department of Agriculture*, Circular No. 413, Oct., 1936.
[7] Tippett, L. H. C. Methods of Statistics. 1st Edn., Ch. X. Williams & Norgate, London, 1931.
[8] *Ibid.*, page 26.
[9] Morton, W. E. Spinning Value of Raw Cotton. *J. Text. Inst.* 1930, T205.
[10] Hancock, H. A. Strength, Grade and Price of Egyptian Cottons. *J. Text. Inst.* In the Press.

Botanical Station,
Ministry of Agriculture,
Orman (Giza),
Egypt.

Received 1/4/37.

NOTE ON "THE GEOMETRY OF CLOTH STRUCTURE"

The transcription of numerous mathematical symbols is liable to error and some instances in the above paper (this JOURNAL, 1937, Vol. XXVIII, T45-T96) call for immediate correction.

On p. T60, line 7 up, read $\sqrt{2c_1}$ for $\sqrt{c_1}$ and $\sqrt{2c_2}$ for $\sqrt{c_2}$.

Equation 28 should read:

$$D = \frac{p_2\sqrt{2c_1}+p_1\sqrt{2c_2}}{1+0{\cdot}2\ (c_1+c_2)-(\delta_1+\delta_2)}$$

In Equation 28*a*, $\sqrt{c}$ should read $\sqrt{2c}$; and in Equation 32, c should read $\sqrt{c}$. The correct forms are used in applications of these formulae throughout the paper.

The full treatment necessary to original publication tends to obscure the essentials and this opportunity is taken to put in a nut-shell a simple statement of the analytical method that is accurate enough for most practical purposes. Using a factor to give a rather closer approximation over the range of normal structures and quantities directly taken from test data, Equation 24 can be put in a form to give the amplitude (h_1 in *mils*) of the crimp of a thread in terms of the *percentage* crimp ($c_1\%$) and the number of *cross* threads per *inch* (t_2).

$$h_1 = 136\sqrt{c_1\%}/t_2 \qquad \ldots \qquad \ldots \qquad \ldots \qquad (24a)$$

The sum of the amplitudes equals the sum of the normal diameters,

$$h_1+h_2=b_1+b_2$$

and the diameter (in mils) of the rounded thread, $d=36/\sqrt{N}$, where N is the count in the cotton system. Hence is obtained immediately the degree of flattening, $e=b/d$. The analysis of changes in yarn length, flattening and crimp balance follow as in the many examples given in the paper, where more precise formulae are used. The calculations may be made precisely enough with a slide rule.

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

11—STRENGTH, GRADE AND PRICE OF EGYPTIAN COTTONS

By H. A. HANCOCK, B.Sc.
(Spinning Technologist to the Ministry of Agriculture, Egypt)

SUMMARY

1. All the varieties composing the Egyptian crop are described, and their chief staple measurements and their yarn strength at a standard count are tabulated, from observed data on fully representative samples.
2. The causes and effects of " grade " are discussed, and it is shown that the percentage of taker-in waste is a good index to grade if the variety is known.
3. It is shown that there is a close relationship between the yarn strength at a given count and the spot price of all kinds of Egyptian cottons.

Many changes have taken place in the constitution of the Egyptian crop during the past ten or twenty years, and the time seems ripe for a review of the present situation. Since 1918, at least twenty different varieties of cotton have been at some time or other on offer at Alexandria, although many of them have had only a very brief existence. The effort of keeping up to date has apparently been too much for the reference books ; a Year Book published in 1936 refers to Sakel as a promising new variety : this was true twenty-five years ago, but may be regarded by now as a little too conservative. Actually, most of the new varieties have never reached a sufficiently large crop to cause much disturbance, and until recently Sakel and Ashmouni have usually accounted for about 90 per cent. of the total crop. Of recent years, Sakel has declined in favour of a new high yielding cotton called Giza 7 ; and by 1936 the " other varieties " had also been eliminated by this competition to such an extent that 99 per cent. of the crop was made up by the five main varieties remaining (Fig. 1).

Taken in their order of importance judged by acreage, the varieties at present cultivated are :

Uppers Ashmouni. The Ashmouni variety grown in Upper Egypt (i.e., south of Cairo) has maintained its type, apparently with only slight alteration, for three-quarters of a century ; in spite of all competition from the new cottons, 99 per cent of the cotton grown in Upper Egypt is Ashmouni. In 1925 the original Ashmouni seed was substituted by Giza 2, a Government selection from Ashmouni of slightly higher yield ; and in 1933 this was again substituted by Giza 19, a further Ashmouni selection of slightly higher yield and strength. The plant is vegetatively indistinguishable from the original, and is still known as Ashmouni. Uppers makes a good, clean, strong yarn, and is commonly spun into counts up to about 60's.

When Ashmouni is grown in the Delta its quality is slightly different, and it is distinguished by the name Zagora; any variety grown in the Delta gives a coarser staple than if grown in Upper Egypt, but Ashmouni is the only variety so widely distributed as to call for separate names. Zagora was originally a variety propagated about 1917 by the late Mr. Nicholas Parachimonas, who named it after his birth-place, a village in Greece; it was closely similar to Ashmouni, from which it was almost certainly a selection. Gradually the seed became replaced by Ashmouni, until by about 1930 none of the original seed remained, and all the cotton now grown under this name is really the Giza 2 and 19 strains of Ashmouni. The crop is of about the same staple length as Uppers but is somewhat coarser, and spins about 5 per cent. weaker yarn, being the weakest of the Egyptian

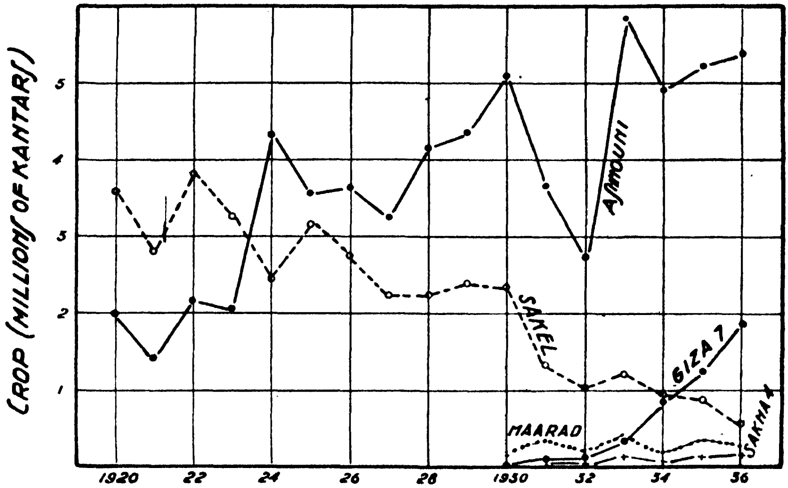


Fig. 1. Approximate crops from 1920-36 of the Egyptian varieties under cultivation in 1936.

cottons. Much of its cultivation is in the hands of small growers, and the crop as a whole tends to be of rather lower grade than the average.

Giza Seven. This variety was introduced by the Botanical Section of the Ministry of Agriculture, whose research laboratories are situated not far from the famous pyramids at Giza; the place-name is subject to personal preference in its transliteration from Arabic characters, and it is also printed as Gizah, Gizeh, or Guizeh. Introduced in 1930, Giza 7 has rapidly come into favour with cultivators because of its good quality associated with high agricultural yield, and the crop is now about equal in volume to the Sakel crop of six years ago. The original plant was found in an Ashmouni field, and was possibly, in the first instance, a natural hybrid between Ashmouni and Sakel; it is particularly remunerative in the Delta, and has a high degree of immunity to wilt disease. Although the cotton has a staple shorter and coarser than Sakel, it is peculiar in that it gives a yarn strength higher than would be expected from its staple measurements, and is not very much inferior to Sakel, particularly in the lower grades; prior to the introduction of the law prohibiting mixing of varieties in Egypt, it was often accepted as Sakel. Although not as white as Sakha 4, Giza 7 is one of the lightest in shade of Egyptian cottons, and spins successfully up to 80's or 100's combed.

Sakel. A variety first introduced about 1910 by Mr. Jean Sakellarides, a Greek broker of Alexandria, who is reputed to have selected it from an odd handful of seed cotton which he noticed to possess long silky staple; yarn as fine as 200's has been spun from this cotton, which in the best examples has a length of staple about 1½ inches. The Sakel plant is said to have an affinity for the salty soils of the Northern Delta, and the crop was in both senses of the word the staple crop of the Delta for many years. The seed type has been twice replaced by slightly improved selections; by a pure strain selection known as No. 310 in 1925, and by a Botanical Section selection known as Sakha 7 in 1933. In both cases the plant was unchanged in appearance, and the name Sakel was retained. Unfortunately the type is very susceptible to wilt disease (*Fusarium*), and it does not appear possible for the breeders to select plants which are at once immune to wilt and yet true to type in other characters (but see Sakha 4, below); it is also late in maturing, and much of the crop is lost or damaged by the depredations of various plant pests. Sakel gives a yield about 40 per cent. less than Giza 7, and an increasing number of spinners are changing over to the cheaper variety. There appears little doubt that Sakel will shortly vanish altogether from the Egyptian market; the only question is how long the process will take—some authorities place the time as only three or four years distant.

It is sometimes asserted that Sakel has steadily deteriorated in quality since its introduction, but in good years the higher grades appear as good as ever they were. There is, however, reason to suppose that the Sakel sold now in low grades may be weaker than any Sakel sold 25 years ago, owing to the ravages of the pink boll worm; when Jean Sakellarides first produced his famous variety, the pink boll worm was just about to appear in Egypt.

Maarad. Selected and introduced by the Royal Agricultural Society from a Pima* parent, Maarad is distinctive in plant type and in lint from most other Egyptian cottons. The average staple is longer than Sakel, being a full 1½ inches; the cotton is lustrous and of dark shade, but does not spin so strong a yarn. Maarad is in demand especially in Japan, and spins satisfactorily up to about 120's counts. This cotton is grown on a much smaller scale than the varieties previously mentioned, having remained steady at a production of about 5 per cent. of the whole Egyptian crop for some years past; it first appeared about 1926.

* Pima was derived from Mit Afifi seed introduced to Arizona from Egypt about 1900.

Sakha 4. This is a selection from Sakel which is immume to wilt disease, introduced by the Botanical Section of the Ministry of Agriculture in 1930 for this reason. Although the plant cannot be distinguished from Sakel, the lint is noticeably different, being much lighter in shade, more lustrous, and longer in staple; it appeals to the ginner because the seed cotton yields a high percentage of lint. Sakha 4 was immediately liked by the graders, but in spite of its qualities did not at first find favour with spinners because the yarn—however attractive—did not attain the strength expected from its staple; the crop has therefore remained of small volume, about equal to Maarad. In 1936 a substrain of Sakha 4 selected for hair-properties began to be substituted for the original seed, the name remaining unchanged; the new Sakha 4 is of slightly higher yield than the old, but is much superior in yarn strength, so that this variety may be expected to progress in the future. As will be seen from the spinning-tests recorded below, Sakha 4 in 1936 gave a higher yarn strength than Sakel, and has spun satisfactorily in

counts as fine as 150's. Being wilt immune and also being cultivated chiefly by the larger landowners, Sakha 4 is the highest grade crop grown in Egypt; 62 per cent. of the 1935 crop was graded over "Good."

Fouadi. Named after H.M. the late King Fouad of Egypt, Fouadi was the latest of the cottons to be introduced by Parachimonas. It appeared about 1926, reached 50,000 acres in 1933, but is now losing ground, presumably to Giza 7 which it somewhat resembles. Other cottons produced by Parachimonas were Abassi (a very white cotton), Nubari and Pilion, all of which enjoyed some popularity but are now extinct.[1]

Giza 3. This super-Ashmouni type was propagated because of its ability to withstand boll-shedding at the high temperatures in the extreme south; it has had only a limited appeal, and the crop has always been very small. What little there is of the variety is now losing ground to Giza 12, and it is likely to vanish altogether in the near future.

Two more Botanical Section varieties have sufficient promise to justify mention here, although both are as yet in their first year or two of commercial propagation :—

Giza 26. Originated from a cross between Sakel and an off-type Sea Island cotton. The plant resembles Maarad, as does the lint in that it is dark in shade and longer than Sakel; but the cotton has the merit of producing the strongest yarn of any Egyptian variety. Its strength is at least 5 per cent.—10 per cent. greater than Sakel. The agricultural yield is higher than Sakel on present evidence, but, like Sakel, the plant is susceptible to wilt. The 1937 crop is estimated to be about a thousand bales. With the passing of the Sakel variety, therefore, two varieties become available to replace it even in the finest counts—Giza 26, which is of darker shade and much stronger; and the improved Sakha 4, which is lighter in shade and of equal strength.

Giza 12. Originating in a cross between Sakel and Ashmouni, this cotton has proved itself the highest yielder of any variety grown in the Delta, and is, moreover, immune to wilt disease. . It is one of the few varieties that show sign of any promise in Upper Egypt. The staple is longer, darker, and of rather lower spinning value than Giza 7, but has the desirable feature of being exceptionally free from nep during spinning; it is much nearer to Giza 7 than to Ashmouni in spinning quality, although it has Ashmouni yield. About 5,000 bales were grown in 1936, and 15,000 are estimated for 1937.

YARN STRENGTH AND STAPLE CHARACTERS OF THE CHIEF VARIETIES

In describing Egyptian cottons it is as necessary to specify the grade as it is to name the variety. Grade dominates quality to such an extent that the lowest grades of Sakel are not much superior in carded yarn strength to the highest grades of Ashmouni. The order of the grade names in use is (from lowest quality to best): Fair, Fully Fair, Good Fair, Fully Good Fair, Good, Fully Good, and Extra. In addition, half grades are designated, as e.g., G/FG (intermediate between Good and Fully Good); quarter grades are shown by a plus or minuss ign, e.g., Good plus a quarter; and ⅛th grades by the terms "strict" (equals ⅛th grade high), and "about" (equals ⅛th grade low). In order to give an idea of the relative values, the trend of prices for some of the Sakel grades in 1935–6 is shown in Fig. 2. The average grade of the whole crop is around FGF/F; cotton graded below FGF is usually the crop of a second picking.

In addition to classification by grade, two types of staple are also recognised for each variety—" good " staple and " ordinary " staple ; these terms should not be confused with the grade descriptions, and are applied

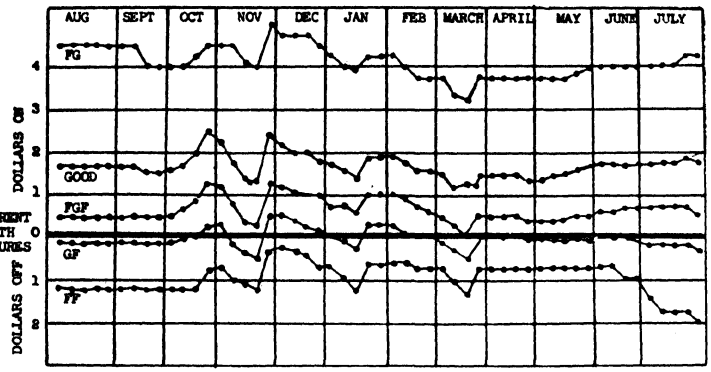


Fig. 2. Spot prices at Alexandria of five grades of Sakel, season 1935–36. (Two dollars at Alexandria are roughly equal to 1d. per lb. at Liverpool).

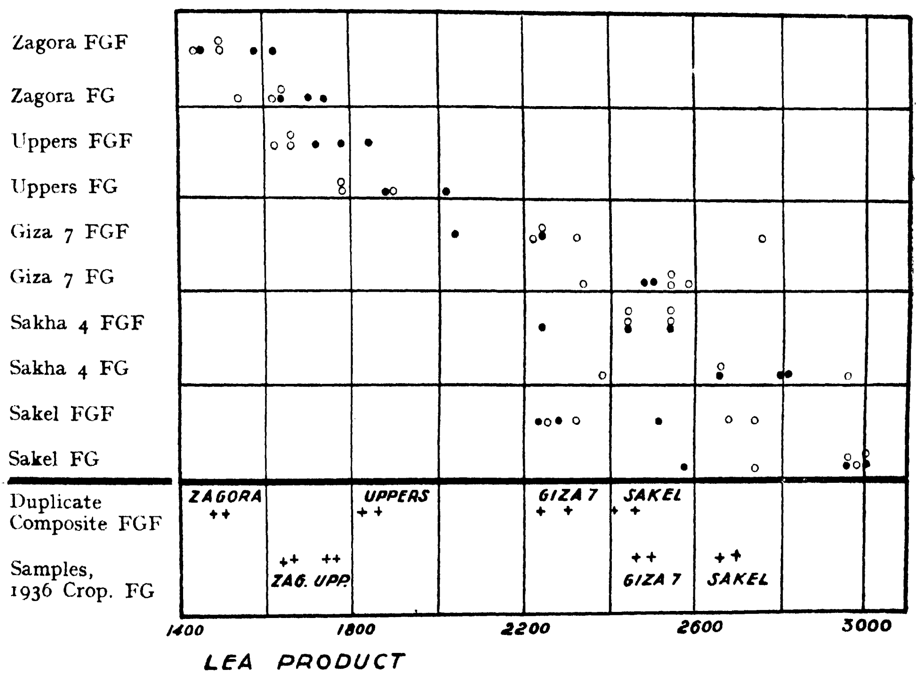


Fig. 3. Variability in strength (60's carded) between different deliveries of the same grade and variety ; each point is the mean of 24 lea tests, dots for 1934 crop, circles for 1935 crop. In 1936 two composite samples were made up from 15–25 different trade sources for testing purposes, and the variability was much reduced.

to cottons grown in the best and in the average districts respectively. The price difference between good and ordinary staple is small, being the equivalent of less than a quarter grade as a rule ; all the cottons for which test results are given here were of good staple.

Two grades in each variety have been selected for spinning-tests, namely Fully Good Fair (FGF) and Fully Good (FG); these represent cotton slightly below the average of the crop, and cotton near to the best of the crop. All cottons without exception were Alexandria graders' type samples, abstracted from bulk deliveries sold in the ordinary course of business to spinners all over the world; they are in no sense experimental growings.

In 1934, and again in 1935, three or four samples of each variety and grade were obtained from different merchants, and all were spun at around the same time in 1935, involving about 100 separate spinnings. It was found that samples nominally the same varied considerably, as shown in Fig. 3. In 1936 it was not found practicable to spin this number of samples, and in order to reduce the sampling error to reasonable proportions, composite samples were made up drawn from 15 to 25 different trade sources for each grade and variety. The sampling error was thus reduced to negligible proportions, and these testings may be regarded as truly representative of the crop for that year. All the spinning-tests are summarised in Table 1; the card waste percentages are the sum of two cardings, and are discussed later.

Table I Summary of Spinning-Tests on the Commercial Crop of 1936
(Average of 1934 and 1935 Crops in brackets)

	Lea Product 60's carded 3·6 t.f.	Card Waste (taker-in) %	Staple Length 1/32nds inch	Hair Weight ·00mgm/cm	Spot Price $ per Kantar
Sakel					
FG	2675 (2880)	4·1 (3·9)	45 (46)	133 (136)	22·4 (19·2)
FGF	2430 (2430)	6·2 (6·4)	45 (45)	130 (134)	18·6 (15·7)
Sakha 4					
FG	2720 (2720)	4·4 (4·1)	46 (49)	130 (134)	21·2 (18·7)
FGF	2550 (2450)	5·7 (5·5)	45 (46)	123 (123)	17·7 (16·0)
Maarad					
FG	2530 (2620)	3·5 (3·3)	47 (49)	132 (134)	20·3 (18·0)
FGF	2345 (—)	5·4 (-)	45 (—)	124 (—)	17·6 (16·0)
Giza 7					
FG	2485 (2490)	4·7 (5·2)	43 (44)	146 (150)	18·6 (17·0)
FGF	2275 (2285)	7·4 (7·8)	42 (44)	138 (148)	15·1 (14·8)
Giza 12					
FG	2335 (2305)	5·0 (4·5)	44 (45)	145 (154)	17·2 (—)
FGF	2095 (2135)	7·4 (7·1)	44 (44)	135 (140)	14·1 (—)
Uppers					
FG	1745 (1860)	7·4 (6·4)	39 (40)	180 (184)	15·0 (14·8)
FGF	1830 (1710)	10·8 (10·0)	39 (39)	152 (179)	13·4 (13·4)
Zagora					
FG	1650 (1645)	6·8 (7·6)	40 (39)	184 (196)	14·7 (14·2)
FGF	1485 (1520)	9·6 (10·8)	39 (39)	180 (181)	13·3 (13·2)

Notes:

Staple length is determined from the Balls Sorter Diagram, and closely agrees with the estimates given by graders.

Spot prices are given in Alexandria dollars per Kantar of approx. 100 lbs.; the figure for 1936 crop is the first half of the season, i.e. from Sept. 1936 to Feb. 1937. To convert these figures approximately to pence per lb. at Liverpool, divide by two.

Many points of practical importance arise out of this series of tests, which is almost certainly unique; not only are the samples truly representative of their type, but the spinning conditions and counts spun are constant for all, and they are on a strictly comparable basis.[2]

Undoubtedly the most striking feature of the tests is the reduction of yarn strength shown in the lower grades; it is greatest with Sakel, and is much less with Sakha 4. At grade FGF, Sakha 4 is substantially stronger than Sakel, with Maarad and Giza 7 not far behind. Giza 7 FG sometimes sells at a lower basis than Sakel FGF; on these occasions a spinner substituting Giza 7 for Sakel obtains not only a stronger yarn, his cotton is also of better grade at the lower price. Giza 12 is seen to be much nearer to Giza 7 than it is to Ashmouni.

It is interesting to note that Ashmouni (Uppers and Zagora) stands clear away in all characters from the other Egyptian cottons. This is also found in plant breeding work; there is every conceivable gradation in staple from Giza 12, up to and well beyond Sakel; but the gap between Giza 12 and Ashmouni stands almost unbridged. A cotton appears to be either Ashmouni, or else something quite different.

An important feature of 1936 Uppers is disclosed; the Fully Good is rather weaker than in past years but Fully Good Fair is stronger, so that we have the unusual occurrence of the lower grade being the stronger cotton. The high strength of 1936 FGF Uppers arises from its low hair weight; July 1936 was exceptionally hot and the crop matured unusually early. How precisely the later picks alone were affected is not clear, but the result is unquestionably real, and was confirmed in duplicate spinnings. Other samples spun earlier in the season also showed the effect.

On the same strength scale, the new long stapled cotton named Giza 26, which has just begun to be propagated, gives a lea product well over 3,000 in grade Fully Good; it is thus far superior to Sakel or any other of the established varieties.

Fairly parallel strength results are obtained with all the cottons listed, whatever the counts or strength level to which they are spun, and whether they are twist or weft yarns, provided the cottons compared are treated identically; e.g., Sakha 4 is always stronger than Maarad, or Giza 12 than Uppers. This generalisation holds whether the cottons are carded or combed quality, but if combed, the waste percentage must be constant.[2]

The lea products given in the table may be used to estimate the yarn strength of any of the listed cottons spun in any yarn in any mill, provided that the lea product of *one* of the listed cottons spun under the particular conditions is known. Thus if a mill spinning a yarn of known lea product (P) from Giza 7 FG wished to estimate the lea product (X) of a yarn spun under the same conditions from Sakha 4 FGF, then sufficiently closely for many purposes

$$X = P \times 2550/2485$$

by simple proportion from the 1936 figures given in the table.

CAUSE AND EFFECTS OF LOW GRADE

One of the limiting factors to the yield is the prevalence of various plant pests, especially boll-worm, towards the end of the season. Even at the beginning of the season a small percentage of bolls is attacked, but at the end nearly all the bolls then maturing are in some way defective and it becomes no longer profitable to pick the cotton. Early on, when the attack is light,

only one loculus of the bolls may be actually infected; and although the remaining two loculi are frequently affected, producing short or thin walled cotton lacking in lustre, such cotton is not excessively weak and is usually unstained. As the season progresses, a larger proportion of damaged bolls occurs; more bolls with two and with three damaged loculi are found; a bigger proportion of weak, stained, immature cotton is included with the good cotton. Finally a black fungus appears which has further disastrous effects on the length and strength of the cotton in the damaged bolls, and completes the wreckage. By sorting out the damaged bolls, or by picking early, the cotton may be kept up at high grade, but it is not always economic to do so.

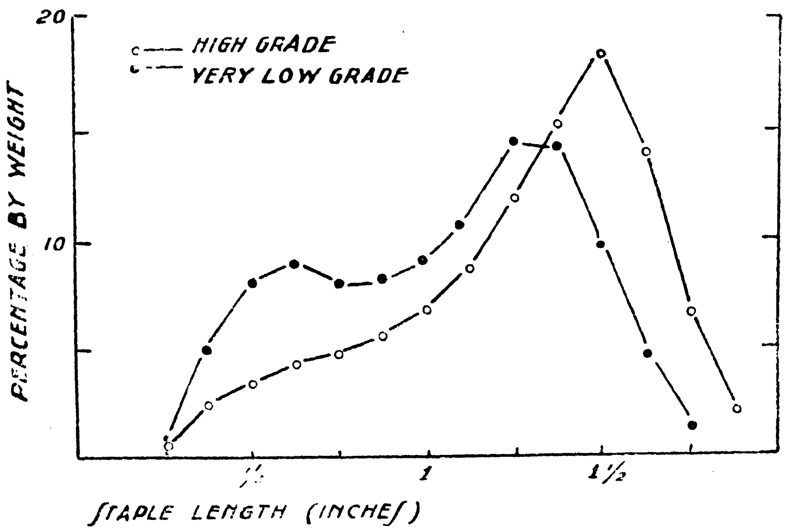


Fig. 4. Balls Sorter Diagrams for a high grade and a low grade Giza 26; the excess of short fibre, and the general reduction in staple length of the low grade is clearly shown. These samples are extreme cases, being the same as the highest and lowest points of Fig. 5.

The percentage of damaged bolls present is the essential factor determining the grade. A grader does not classify merely according to the amount of leaf and similar impurity present, he also considers the bloom or lustre, and the proportion of stained cotton. A genuine and typical FGF cotton cannot be formed by the addition of leaf, etc. to FG cotton; but it can be formed by the addition of cotton from damaged bolls to FG cotton. This circumstance throws light on the otherwise puzzling behaviour of low grades in carding.

It is found that low grades give high percentages of taker-in waste at the card, and in fact the percentage is a fair index to grade within a given variety; unfortunately the waste/grade relation varies from one variety to another, so that the grade can only be estimated from the waste when the variety is known (Table 1). This correlation might be thought surprising when it is remembered that most of the taker-in waste is cotton—the seed coat, leaf, sand, etc., amount to less than one third of the waste in many cases; moreover, if the cottons are carded a second time, the amount of waste is still inversely proportional to grade, although practically the whole of it is now

simply cotton. These observations confirm that low grade differs from high grade not merely in the amount of impurity present, the character of the staple is changed. It is changed by the increased proportion of short, broken, or immature hairs from the damaged bolls in lower grades, and this is the cotton making up a part of the taker-in waste. Similar remarks probably apply to the percentage of comber waste removed at constant settings.

Besides being short, much of the boll damaged cotton is immature, and it is the thin-walled and (so called) dead hairs which give rise to the commonest form of neps in yarn. It can hardly be doubted that the percentage of boll-damaged cotton (i.e. the grade) influences the "maturity coefficient" of Peirce and Lord,[3] when the variety varies, the coefficient is presumably subject to similar limitations as is the percentage of taker-in waste, used as an index to grade. Methods of estimating the grade of cotton in a given yarn sample would seem to be well worth the trouble of seeking; grade of cotton is usually ignored in yarn or cloth analysis, although the information is nearly as vital as the name of the variety, to a spinner wishing to match the material.

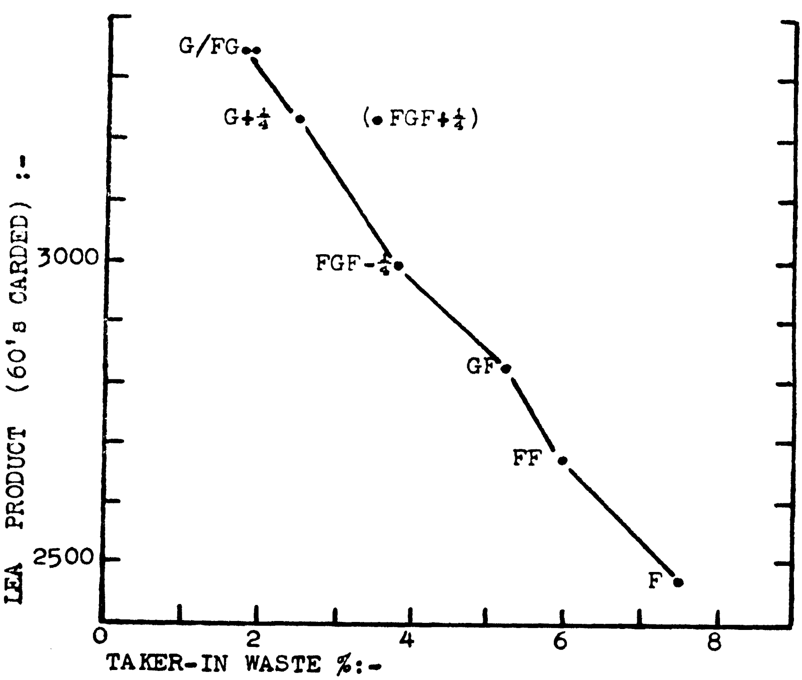


Fig. 5. Relation between yarn strength (60's carded) and percentage of taker-in waste for Giza 26. The grader's classification is given alongside each point. The lower grades contain a large percentage of boll damaged cotton, which weakens the yarn and increases the taker-in waste.

Since both graders and spinners normally base their estimation of staple length on the longer hairs only, lower grades are commonly recorded as being about equal in staple to higher trades. Although "wasty" staple can be recognised without the aid of instruments by a skilled classifier, it is only when the full distribution of staple length is displayed as in a sorter

diagram that the characteristic of low grade becomes clearly apparent; an increased proportion of short staple is invariably found (Fig. 4).

The association between low grade and irregularity of staple length has given rise to the belief that regularity of staple is an essential character to be selected for in plant breeding research. This impression is fallacious, for provided boll-damage does not enter into the story, such differences of staple length irregularity as are found between Egyptian varieties are of little importance, and many cottons are known which produce a good strong yarn in spite of irregularity of staple. It is the type of staple irregularity associated with the other defects of low grade cotton that causes objection. When the character of boll-damaged cotton is realised, it is no longer surprising to find that it causes weaker yarn (Fig. 5).

Even so brief a discussion on grade as this would be incomplete without a reference to the extraordinary skill of the Alexandria graders. These expert

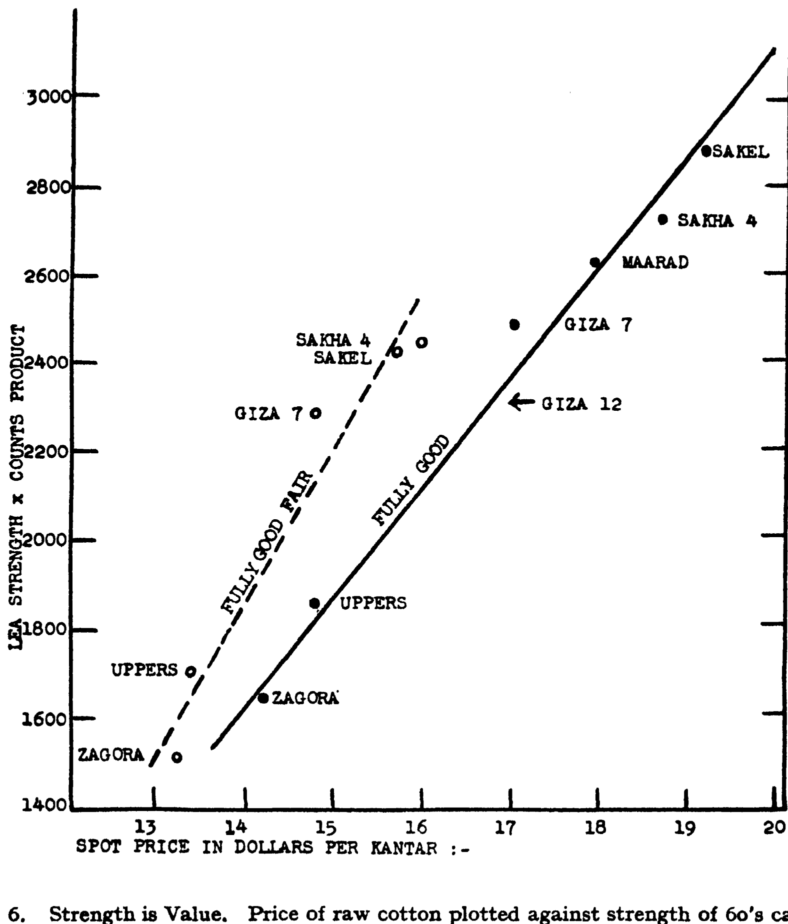


Fig. 6. Strength is Value. Price of raw cotton plotted against strength of 60's carded yarn spun the from it shows a straight-line relation at constant grade. The figures are average of the 1934 and 1935 crops. Giza 7 was cheaper during the period than would be expected from its yarn strength. Giza 12 was newly introduced and spot prices were not available; an estimate of the expected price can be made from the graph, since the strength is known. To convert Alexandria dollars to approx. pence per pound at Liverpool, divide by 2.

classers claim to distinguish between samples only one eighth of a grade apart; in the case of FG Sakel for example, this represents the discrimination by hand and eye of a difference in taker-in waste amounting to only 0·12 per cent; the difference in lea strength associated with this grade difference is half a pound at 60's. A newcomer to this industry can only look on with admiration. Although they may know little or nothing about spinning, and although they may be less successful in their estimation of yarn strength based on staple length, etc., yet from their consideration of bloom, leaf and stain, the graders arrive at the estimation of a complex quantity which is very much to the point as far as spinners are concerned.

YARN STRENGTH AND COTTON PRICE

The yarn strength of Egyptian varieties in grade Fully Good is found to be closely related to the spot price of the cotton at Alexandria, plus some basic amount dependent upon economic conditions. At a given grade, therefore, the spinner pays for yarn strength as recorded on his lea tester, and he evidently pays only surprisingly small premiums for lustre, colour, length of staple and so on. At lower grades there is a similar strength/price correlation, less precise and at a lower price level (Fig. 6). Owing to transient changes in supply and demand, and other causes, the price of a variety may for a time deviate substantially from that expected on merit, but in the long run strength is value.

Since strength is the essential characteristic of cotton textiles, the result is not unexpected; but the closeness of the correlation is a striking testimonial to the versatility of the lea test, which is here used as the sole criterion of quality. The writer is not aware of any published justification showing that lea tests on yarns are a measure of any quality in a finished article; probably it is sufficient justification that so many people use the test. Weavers commonly use it as a forecast of some quality they expect to get in their cloth; spinners swear by it, and in fact for a given class and count of yarn the lea strength is usually used as a measure of yarn quality without reference to any other character. To the uninitiated eye the lea tester dial is a very ordinary scale graduated in pounds weight, but the weaver can see on it shillings per piece of cloth, and the spinner sees pence per pound of yarn, clearly marked; my cotton growing friends now observe that this magic scale is really graduated in Egyptian characters, and that its translation reads—£ s. d. per bale of cotton!

REFERENCES

[1] *Egyptian Gazette*, Alexandria, October 24th, 1936.

[2] Hancock, H. A.; "A Spinning Procedure for Cotton Samples; *J. Text. Inst.*, 1937 **27** T161

[3] Peirce F. T. and Lord E.; E.C.G.C.· Conference on Cotton Growing Problems 1934, Report of Proceedings, p. 229.

Botanical Section,
Ministry of Agriculture,
Orman (Giza), Egypt.

Received 1/4/37

12—A COMPARATIVE EXAMINATION OF METHODS OF ANALYSIS OF WOOL FOR FIBRE DIAMETER AND LENGTH

Part I—Diameter Measurements in Wool Tops

By G. R. STANBURY and H. E. DANIELS

(Wool Industries Research Association)

I. Introduction.

In 1931, accounts were published in this *Journal* by Barker & Winson[1,2,3] of the relationship between fibre diameter* and wool quality in combed tops. The method used consisted in the weighing of a counted number of fibres cut to a definite length. From several places along the top, small samples were taken between the thumb and finger and separated laterally from the top. A bundle of fibres of suitable size was then carefully parallelised and clamped into position on a special instrument designed for cutting a fixed length of fibre, the distance between the blades being less than the shortest fibre length present. Five-hundred fibres were counted out, cleaned, and their dry weight determined.

This method is slow and laborious. The straightening of every fibre in a bundle prior to cutting is a matter of extreme difficulty and there is a consequent uncertainty attaching to the value of the measured length for weighing.

There is a definite disadvantage also in the fact that a mean value only is obtained. A knowledge of the dispersion of the individual fibre measurements about the mean value is of importance not only in relation to the spinning power of the wool, but also as a means of assessing statistically the magnitude of the errors involved in measuring such a sample.

This disadvantage is also characteristic of Küsebauch's lanometer method in which the volume occupied by a given number of fibres is measured.

Serious errors can also arise in both these methods as a result of faulty sampling technique, which will introduce a lack of randomness into the selection of the fibres to be measured. This is dealt with fully in Section III.

A photographic method based on the measurement of fibre cross-sections which was used by Winson for some of the lower qualities, is also not very satisfactory. It is difficult to assess the effect on the size of the cross-section of all the various reagents and processes to which the wool is subjected before the final section is ready to be photographed. It was used because it was thought that discrepancies would arise between the results obtained for the lower qualities by the weight per unit length method and the actual measured diameter owing to the presence of large numbers of medullated fibres in these qualities.

II—The Adoption of Standard Methods of Measurement.

In recent years, a technical committee of the International Wool Textile Organisation has re-examined the whole question with the object of setting up standard methods of fibre measurement, and agreement has already been reached with regard to the method for fibre diameter.

---

* The word "diameter" is used throughout the paper without any assumption of circularity. It seems to be less ambiguous than a reference, e.g. to "the fineness of a coarse fibre."

This method involves the measurement of the profiles of optically projected images of a large number of fibres at known magnification. It was agreed that the magnification should be 500 × and that the projected images of the fibres should be measured to the nearest 1 mm., i.e. to 2 microns.* A fibre, e.g. between 10·5 and 11·5 mm. on the screen would be classed 11 mm. or 22 microns.

It was also agreed that the fibres should be mounted in cedar wood oil, this having the useful effect of clearing the image of the fibre and showing up its edges as fine lines suitable for measurement. It has been previously shown by numerous workers that the cedar wood oil produces no swelling effect at all on the fibres.

In order to determine the most satisfactory and efficient method of sampling, it was agreed that each country represented should measure up four tops, to be supplied by the laboratories of the Leipziger Wollkämmerei, by a number of different sampling methods. The measurements carried out at Torridon on these tops and the conclusions based on a statistical analysis of the results are given in detail in Section VI. It can be stated here, however, that a very satisfactory sampling method for diameter has been evolved, the differences between the means of successive samples being only of the order to be expected from the actual distribution of diameters within the samples.

III—The Theoretical Basis of Correct Sampling.

The purpose of a sample is to provide information about the main bulk of material whose exact properties it is impossible to ascertain directly. This information may be either qualitative or quantitative. While we are concerned here with quantitative information only, such as, for example, the mean fibre diameter, it should be emphasised that the question of sound sampling is no less relevant to qualitative estimations of the type involved, say, in wool judging, where unrepresentative sampling may well lead to serious error.

Naturally, the estimates of the mean obtained from successive samples will differ among themselves, and from the true mean, owing to the range of individuals to be found within the sample, and also to unavoidable random errors in the method of measurement. We shall call these *controllable* variations, for by increasing the size of the sample indefinitely, the variation in the mean due to these causes can be brought within any desired limits.

In general, however, the variation between sample means will not be accounted for by this alone. The samples may have been selected from parts of the material whose true values differed significantly owing to lack of homogeneity. In such circumstances the material is said not to be statistically uniform, and care must be taken to distribute the selection of material for the sample over as much of the bulk as is practicable.

Another source of variation has to be considered. It is possible that the technique of selecting the sample, or of selecting individuals for measurement is fundamentally unsound in that the operations involved in the method are not properly under control. Erratic variations of an unpredictable character may be introduced, and valid results cannot be obtained from such samples. Moreover, a bias introduced by a fault of technique, or by the omission of some necessary precaution is doubly

* See Appendix I.

dangerous in that the results may present a specious regularity, and ordinary statistical tests will not avail to show up the error. On the other hand, the existence of a bias whose cause is known, such as for example the length bias (to be discussed later) is not in itself necessarily a drawback and may, in view of other considerations, lend added value to the sample.

The two main attributes of a wool top which it is necessary to measure are its mean fibre length and mean fibre diameter, and the same type of sample may not be equally suitable for both.

It is now recognised that there are two distinct types of sample which can be extracted from any longitudinal association of fibres of varying lengths. These types have been dealt with adequately by Townend[5] in this *Journal*, but may be briefly recapitulated here.

In one type of sample, the proportions of fibres of each length group present are the same as in the bulk of the wool, within the limits of random sampling error. Such a sample is called a " true sample " and in a worsted top is obtained by extracting all the fibres which end in the volume enclosed by two cross-sections of the top separated by a distance less than that of the shortest fibre length present. While this condition is theoretically satisfied by the common " worsted draw," it is not by any means easy to attain practically as will be shown in Part 3 of this paper.

In the second type of sample, the chance of a fibre being present in the sample is proportional to its length, as for instance, in the Wilkinson tuft (*see* Townend, *loc. cit.*). Such length biassed samples we propose to call " cross-sectional " samples, since in a top, all fibres crossing a given cross-section constitute a sample of this nature.

The advantages of length biassed samples for work on fibre breakage in processing was stressed by Townend (*loc. cit.*).

IV—Length-Diameter Correlation in Wool Tops.

In diameter measurement, the importance of length bias lies in the positive correlation between fibre length and diameter which persists in the top, although it is probably less marked than in the fleece. Contrary

Table I. Correlation of Length and Diameter in British Selected Tops

Quality	Correlation of Length-Diameter r	No. of fibres in in Sample	1% Limits of r *
80	·26	280	·11—·40
70	·26	296	·11—·35
64	·24	554	·13—·34
60	·29	527	·18—·39
58	·41	668	·32—·49
56	·42	395	·31—·52
50	·43	327	·31—·54
48	·50	285	·38—·61
46	·49	454	·39—·58
44	·33	310	·19—·45
40	·43	336	·31—·54
36	·43	358	·31—·53

to prevalent opinion, this correlation is not very high, rarely exceeding 0·5 ; it is, however, significant, appearing on the average more marked in the coarser wools.

* This defines the range of values within which the true value of the length-diameter correlation for the given top may be expected to lie. See R. A. Fisher *Statistical Methods for Research Workers*, 5th edition.

Table I gives the correlation r of length with diameter in the range of selected tops measured by Barker & Winson. Scatter diagrams are also

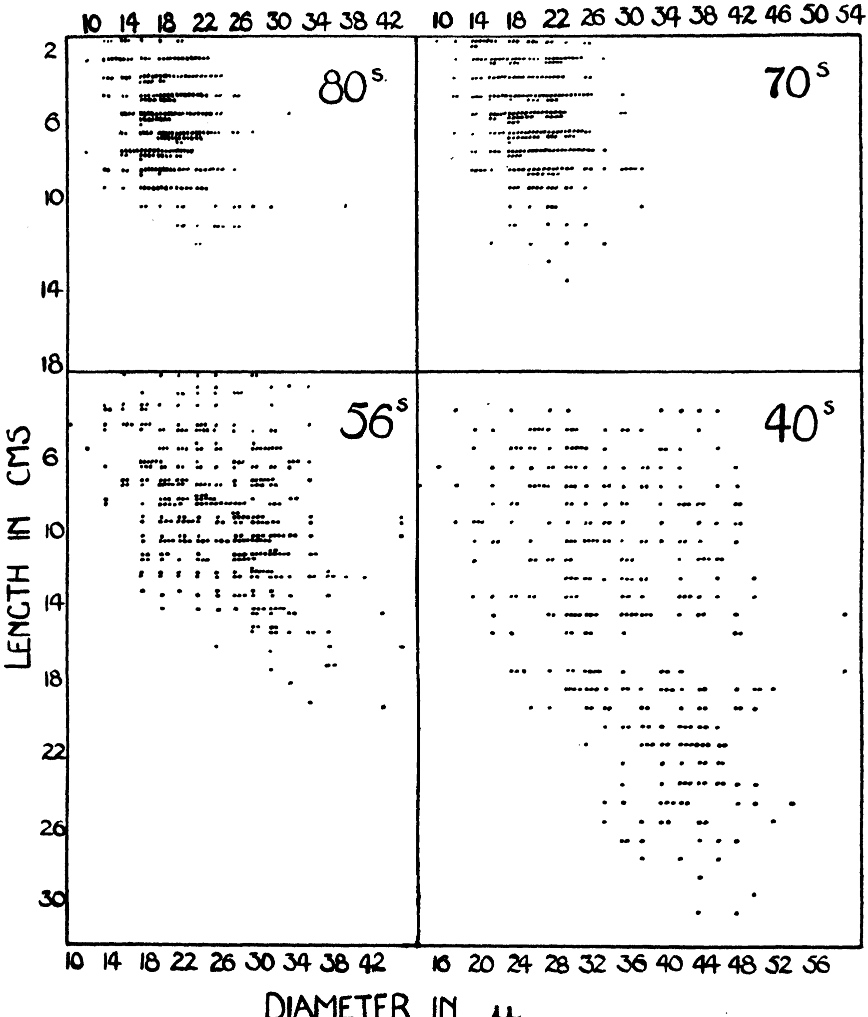


Fig. 1. Scatter Diagrams.

reproduced in Fig. 1. The diameter measurements were made on the comparator, an instrument in use previous to the establishment of the present method: it is unlikely, however, that the order of magnitude of the correlation is very different from that shown here.

Now it can be shown that if D_l is the mean diameter of a length biassed sample, and D_t that of a true sample, then the relation*

$$D_l = D_t + r\sigma_l\sigma_d/L_t$$

will be true on the average, L_t being the mean length of a true sample, and σ_l, σ_d, being the standard deviations of length and diameter in the true sample. Taking as reasonable values for a 60's top

$$r = 0{\cdot}3,\ \sigma_l = 3{\cdot}0 \text{ cm.},\ \sigma_d = 5{\cdot}7\mu,\ L_t = 7{\cdot}4 \text{ cm.}$$

then

$$r\sigma_l\,\sigma_d/L_t = 0{\cdot}3 \times 3{\cdot}0 \times 5{\cdot}7 \div 7{\cdot}4 = 0{\cdot}7\mu$$

$$\text{i.e. } D_t - D_l = 0{\cdot}7\mu$$

* See Appendix II.

In the example quoted this difference between mean diameters of the cross-sectional and true samples amounts to half a quality difference so that the effect of length bias on diameter measurements cannot be ignored.

The finger and thumb method of selecting bundles of fibres for measurement used by Winson (*loc. cit.*) falls between the true sample and the length biassed sample.

In such a case the length bias is difficult to estimate and may vary from sample to sample and from top to top, giving rise to inconsistent results. Such methods are best avoided.

V—Value of the Cross-sectional Sample.

The cross-sectional sample has a peculiar importance in the determination of the mean diameter of the fibres in a top for the following reason. The number of fibres which can be packed into a given cross-section, and the manner in which the fibres lie together, will depend on the distribution of fibre diameters over the cross-section of the top, sliver, or yarn, and this in fact is just what is given by the cross-sectional sample. Thus in its relation to spinning power and spinning limit count on which the present quality grades were originally based, the cross-sectional sample is of greater value than the true sample.

In other work, such as the evaluation of length-diameter correlations, it may still be necessary to use true samples.

VI—Investigation of Sampling Methods

The methods of sampling referred to in Section II which were recommended for investigation were as follows:

(a) The 2 cm. cut method.
(b) The worsted draw method.
(c) The Wilkinson tuft method.
(d) The "Dischka" 2 mm. cut method.

We shall proceed to examine these methods in detail and give the results of our own measurements.

(a) This method was advocated by some of the members of the Committee. A 2 cm. length is cut from the top and small samples selected from it with forceps. The fibres are then mounted on a slide in cedar wood oil and spread out so as to avoid any overlapping, at the same time keeping the fibres approximately parallel. Two hundred fibres are then measured, using the standard projection microscope system. Another slide is then taken and a further 200 fibres measured. It was suggested that these two samples would be sufficient if their means differed by less than one micron, but that if the difference was greater than this, a further 200 fibres should be measured.

In our own tests, six samples were taken up for the two coarse wools and four for each of the two fine wools, the results being given in Table II.

Table II

(All values in microns, each sample 200 fibres).

Top		New Zealand 5169	Monte Video 5182	Monte Video 5186	Australian 9535
Sample	1	29·84	26·19	21·25	18·32
	2	32·60	26·35	21·49	18·88
	3	31·80	25·07	21·09	18·56
	4	29·62	26·93	20·79	18·80
	5	30·93	26·22		
	6	30·63	27·21		
Mean ..	..	30·90	26·43	21·16	18·64

While for the two finer wools this method gives fairly good inter-sample agreement, with the coarser wools, the presence of uncontrollable variations between the means seems to be evident. Analyses of variance have been performed on each set of results, the following for the New Zealand 5169 top being typical:

	Sum of Squares.	Degrees of Freedom.	Variance.	Standard Deviation.
Between Samples	5·8039	5	1·1608	$S_1 = 1{\cdot}08$
Within Samples	402·3513	1194	·3370	$S_2 = {\cdot}58$

$$z = \log S_1 - \log S_2 = {\cdot}618$$

The above process compares the observed standard deviation between sample means with that which would be expected to arise from the variation within the samples. R. A. Fisher's table of z indicates that as large a value of z as ·618 would have been exceeded less than once in a hundred times had the variation between sample means arisen entirely on account of the variation within the sample. The existence of what we have called "uncontrollable variations" is thus definitely established and the grand mean of the samples cannot therefore be accepted with confidence.

This is largely due to the fact that the method gives neither a true sample nor a properly length biassed one. It is in fact almost identical with that used by Winson. This method of sample selection is especially dangerous if measurements are being made on a blended top. When a number of different qualities of wool are being gilled together, the fibres of each "end" retain their propinquity to a great extent in the drafted sliver, and the results cannot be representative unless a sample is taken across the whole of its cross-section.

Additional possibility of error lies in the fact that only a certain number of the fibres in any bundle was used for actual measurement, whereas, with either a length biassed or true sample, it is essential to measure all the fibres unless the selection of those to be measured can be made perfectly random by a thorough mixing process. With the method used, despite every precaution, it is impossible to avoid the preferential selection of the longer and thicker fibres, which was demonstrated by Townend.

(b) The Monte Video 5182 top was chosen for this test. Six separate draws were made in the usual way by squaring up the broken end of the top and then taking the draw. In each case, the fibres were laid on a slide, mounted in cedar wood oil, and measured along a line perpendicular to the length of the fibres and near the squared end of the draw, to ensure that the short fibres were not omitted.

The results are set out in Table III.

Table III. Monte Video Top 5182

(All values in microns.)

Draw.	1	2	3	4	5	6
Number of Fibres	298	371	321	619	318	407
Mean Diameter	27·00	27·48	27·06	26·30	26·98	27·40
Grand Mean ..	27·11					

As we have already noted, every fibre in the draw has to be measured to obtain consistent results. From a practical point of view, it is not easy to make a draw of less than about 500 fibres, and the presence of a large number of fibres on the slide, makes it difficult to be certain that every fibre has been measured. It has been mentioned that the selection of the worsted draw is a matter of great manipulative difficulty, if reasonable accuracy is required, and this difficulty alone is sufficient to make this type of sample unreliable for diameter measurements.

There is another disadvantage in the draw method of sampling. Measurements always tend to be made near the end of the fibre and thus any possible variation along the fibre is not taken into account.

(c) The Wilkinson tuft samples were selected in the manner described by Townend. Six samples of about 200 fibres were obtained from the top by inserting a needle and thread and capturing the fibres in a loop which was drawn tight. This method clearly leads to a cross-sectional sample, although it only selects one small portion of the whole cross-section and would, therefore be unreliable for blended tops as already noted. Great care was taken to comb out the short fibres not held in the loop of the thread. Attempts were made to lay the tuft directly on to the slide with the fibres parallel to the longer edge of the slide. When the thread had been removed, the fibres in the middle of the tuft were gently separated with dissecting needles, and after mounting in cedar wood oil, every fibre crossing a line across the middle of the tuft was measured. The results, however, were very unsatisfactory, and eventually it was found necessary to separate the fibres in a tuft into three or four length groups, measuring each lot in turn in the manner described above in order that no fibre should be omitted. The process was found in practice not to be unduly long, and the results obtained on six tufts are set out in Table IV.

Table IV. Monte Video 5182 Top

(All values in microns.)

Sample.	1	2	3	4	5	6
Number of Fibres	338	142	142	176	196	310
Mean Diameter	27·48	26·52	27·31	27·78	26·50	27·3
Grand Mean ..	27·22					

There are still fairly large differences between samples, but the results show a definite improvement on those obtained by the 2 cm. method (a) which is confirmed by an analysis of variance. The method has certain advantages in technique over the draw method (b) which it shares in some respects with the 2 cm. method. It is possible to take fewer fibres in each sample, and this not only leads to greater ease of manipulation, but makes it possible to take more samples, which can be taken from different positions along the top.

(d) A method originally suggested by Dr. Dischka to the International Wool Textile Organisation was modified very slightly, the following procedure being adopted. The top was compressed between two pieces of thin card and a clean cut made at right angles to its length by means of strong shears. A second cut was then made about 2 mm. further along the top, so that 2 mm. lengths of all the fibres in the cross-section at that point were obtained. These small lengths were shaken up in cedar wood oil in a small flask to

ensure thorough mixing of the fibres, the proportion of wool to oil being of the order 0·1 gm. of wool to 10 c.c. of oil. After the fibres had been allowed to settle, an aliquot part was removed on to a slide, the necessary mounting oil added, and the first 200 fibres measured. The following results were obtained from six samples taken in this way from the same mixture of fibres.

Table V. Monte Video 5182 Top
(All values in microns. Each sample 200 fibres.)

Sample.	1	2	3	4	5	6
Mean Diameter	27·48	26·97	27·69	26·89	27·54	27·46
Grand Mean ..	27·34					

In this case there seems to be no evidence of the existence of uncontrollable variations between the sample means, and this is confirmed by the following analysis of variance :—

	Sum of Squares.	Degree of Freedom.	Variance.	Standard Deviation.
Between Samples	·5559	5	·1112	S_1 = ·33
Within Samples ..	499·7602	1194	·2507	S_2 = ·50

The standard deviation between samples does not differ significantly from that which would be expected from the variation within the samples.

These results are typical of the high reproducibility which can be attained by the method. This might have been anticipated from the fact that any unevenness present across the width of the top has been eliminated by the process of mixing. Equally simply, any lack of homogeneity along the length of the top could be eliminated by making a series of cuts at intervals along the top and mixing all the cut fibres up together before measurement.

A point of importance is that by virtue of the mixing process, it is quite safe* to use as samples measurements of successive given numbers of fibres (say 200 or 300) as they appear in the field of view of the microscope : this is not true of the other methods. Another advantage of method (d) over methods (a), (b) and (c) lies in the fact that in the measurement of diameter, all parts of the length of the fibre are taken equally into consideration.

In view of its many advantages, the Dischka method has been provisionally adopted as standard at Torridon, and considerable experience with the method has proved beyond doubt that for speed and reproducibility it leaves little to be desired. In all cases, a number of sections taken at intervals along the top are mixed together before removing samples.

A modification of the method is also used for the sampling of yarn for fineness. The yarn is wound on to a hank in the usual way and a number of cuts taken across the whole of the cross section of the hank. For folded yarns it is advisable to make the cut lengths as small as possible (about 1 mm.) to ensure that the individual components and fibres separate out when the sample is shaken up in the oil.

VII—Experimental Features of the Standard Method.

There are a number of practical details which must be borne in mind by those intending to use the method, both as regards sampling and actual measurement.

* In this connection, however, see remarks under Section VII.

In the sampling method described, a concentration of 0·1 gm. of wool to about 10 c.c. of oil was recommended as suitable. This amount of wool corresponds to about six 2 mm. cuts from an average top. Although a certain degree of latitude is allowable, it is found in practice that if the concentration is very different from this, experimental difficulties are introduced. If there is too much wool, the pieces of fibre segregate together and the thorough mixing which is essential to good sampling becomes impossible. If there is too little wool some uncertainty is introduced into the selection of the small bunch of fibres to be measured from the settled layer at the bottom of the tube. It is necessary, of course, to take the sample to be measured from the whole depth of the settled layer.

For the actual measurement, it is necessary to have a microscope system in which focussing is brought about by movement of the slide stage relative to the objective in order to ensure constancy of magnification. An instrument has been designed at the Wool Industries Research Association especially for use with this method which incorporates this and other features.

The magnification should be checked repeatedly, and this operation is greatly facilitated if the thickness of the slide used is identical with that of the glass on which the standard engravings are made, so that eventually they are the same optical distance from the object lens.

It has been found that with insufficient care there is a tendency for the coarser fibres to be overlooked in measurement. Since the central cross-sections of these fibres are further from the surface of the slide, they do not come into focus as easily as the finer ones which constitute the bulk. The possibility of overlooking coarse fibres can be minimised by using a comparatively low power objective, with a consequent good depth of focus, and a high power eyepiece to obtain the necessary magnification. A high power objective with a small depth of focus definitely aggravates this trouble which can be quite serious, as will be seen from the following example.

An observer was asked to measure 200 fibres on a slide as quickly as possible ; his result gave a mean diameter of 22·94 μ, and standard deviation of 6·00 μ. He then repeated the measurements on the same slide, but doing it much more slowly and taking great care to ensure that every possible fibre in the field of view at any one time was brought into focus and measured ; his result now gave a mean diameter of 23·78 μ, and standard deviation of 6·79 μ. A comparison of these figures, confirmed by a study of the actual distribution curves shows that in the first case, a number of thick fibres have been omitted from measurement. Such a possibility must be carefully guarded against.

Uniformity of magnification over the field of view should be checked up, and if there is any distortion at the edges of the screen, this region should be excluded from use during measurement.

It is advisable also to traverse the whole width of the slide in any one measurement. After a very little practice, the density of the fibre pieces on the slide can be so judged that there are about 200–300 fibres in one complete traverse. If the number of fibres is much greater than this, there is considerable overlapping which increases the difficulty of measurement.

In all cases, the top is sampled under ordinary indoor room conditions of temperature and humidity. The effect of temperature alone on fibre diameter is negligible. The effect of hygrometric condition of the atmosphere

has been investigated by Hirst[6] who gives the following typical figures for the relation between relative humidity and wool fibre diameter.

R.H., per cent.	O. (dry)	63	74	78	84	100
Diameter ..	1·0	1·034	1·060	1·065	1·083	1·148

The average inside relative humidity is about 65 per cent. and a change from 60 per cent. to 70 per cent. which is about the extreme range in a normal room, would thus only produce an increase in diameter of 2 per cent. The actual differences caused by the normal variations of relative humidity are negligible compared with the standard error of the sample mean.

VIII—Variation in Mean Diameter along a Top.

A series of tests using the standard sampling and measuring methods, was carried out in order to ascertain the magnitude of the variation of mean diameter, if any, along the top. The New Zealand 5169 top was chosen as being most likely to show up any effect. Six cross-sections were chosen at intervals approximately 15 cm. apart, and four successive samples of 200 were measured at each cross-section. The means of all the samples are given in Table VI.

Table VI. New Zealand 5169 Top

(All values in microns.)

Sample.	Cut 1.	Cut 2.	Cut 3.	Cut 4.	Cut 5.	Cut 6.
1	31·75	31·62	31·84	30·37	30·68	31·36
2	31·97	31·83	32·36	30·91	31·52	32·09
3	32·15	30·78	31·82	32·75	32·40	31·35
4	31·98	32·19	31·21	32·16	30·83	31·58

The following analysis of variance was performed on the results :—

	Sum of Squares.	Degree of Freedom.	Variance.
Between Cuts	·2299	5	·04598
Within Cuts	452·1945	4794	·09433

In this case the variation between means of different cuts is actually smaller than would be expected from the variation within the cuts, showing that there is no significant lack of homogeneity along the top. Table VI also affords an interesting illustration of the kind of reproducibility possible with samples of only 200 when Dischka's method is employed.

IX—Treatment of Results.

(a) The spinning power of a top may reasonably be expected to depend not only on its mean fibre length and diameter, but also on the distribution of these attributes about the mean values. A qualitative estimation of this spread is provided by the frequency distribution curve, and a quantitative estimation by the standard deviation and possibly some other constant such as the " skewness " of the curve. The presence of a double peak or an abnormal number of extreme fibres in the frequency distribution curve will suggest the existence of blending in the top under examination, and this is almost invariably shown up also by a large value of the standard deviation compared with the measured values for the selected tops.

It has been suggested that instead of using the actual frequency distribution, the cumulative frequency or integral curve should be used, since the irregularities which inevitably appear in the frequency curve are smoothed out by the process of addition. While this may be so, there is no doubt that the curve so obtained will be insensitive not only to chance fluctuations of frequency, but to those real differences between distributions which are of interest to us. Thus for the purpose of visual comparison, it is preferable to use the frequency distribution. Until further experimental work has been done on the relationship between the distribution of fibre diameter and length and the spinning properties of the top, it is difficult to decide which constants of the distribution in addition to the mean and standard deviation would be of value. As the presence of a few abnormally thick or abnormally long fibres is known to cause trouble in spinning, it is thought that the skewness β,* might be a useful quantity to calculate. It had been provisionally decided by the International Wool Textile Organisation to calculate the percentage of fibres exceeding the mean $+6\ \mu$, but the usefulness of this rather arbitrary criterion has not been proved.

(b) The calculation of the standard deviation is also necessary to enable us to attach a standard error to the mean diameter, and to test the significance of differences in mean diameter between samples from two different tops.

Consider two tops having estimated mean diameters, $\bar{x}_1$, and $\bar{x}_2$, n fibres having been measured in each case, and having approximately the same standard deviation σ. Each mean has a standard error of $\sigma/\sqrt{n}$ and the difference $\bar{x}_1-\bar{x}_2$ has standard error $\sigma\sqrt{2/n}$.

If the two tops had the same true mean diameter, then $\bar{x}_1-\bar{x}_2$ would exceed 2·58† times this standard error only once in a hundred times by chance. Hence, if $\bar{x}_1-\bar{x}_2$ is as large as $2{\cdot}58\,\sigma\sqrt{2/n}$ it is considered unreasonable that the tops could have had the same true mean diameter, and they are taken to be significantly different.

By increasing n, the number of measurements taken, increasingly small differences in true mean diameter between tops can be shown up as significant. Considerations of time, however, require that n shall not be unduly large. Again, in discriminating between one top and another, differences in mean diameter below a certain limit, although perhaps statistically significant, are not such as to constitute a real difference in quality between the tops from a practical point of view. The number of measurements, n, therefore, should be chosen so that differences which are shown to be statistically significant should correspond as far as possible to real differences in spinning performance. This cannot be done until more is known about the influence of other factors besides fibre diameter on the spinning power of a given top. Provisionally, however, we can find an approximate basis for the limit of discrimination in the fact that differences of less than half the difference between the usual Bradford quality numbers are said not to be practically detectable: this implies that a difference of about 3 per cent. of the mean fibre diameter can be taken as the limit of discrimination.

Such a difference will coincide with that required for statistical significance provided

$$2{\cdot}58\sigma\sqrt{2/n} = {\cdot}03\bar{x}$$

* A measure of the asymmetry of the curve derived from its second and third moments. See Tippett *The Methods of Statistics.*

† See Fisher, *Statistical Methods for Research Workers*, Chapter V.

Now the coefficient of variation of diameter for all qualities is fairly constant at about 25 per cent., so that taking $\sigma/x = 0{\cdot}25$, we find

$$2{\cdot}58 \times {\cdot}25 \times \sqrt{2/n} = {\cdot}03$$

giving
$$n = \left(\frac{2{\cdot}58 \times {\cdot}25}{{\cdot}03}\right)^2 \times 2 = 925.$$

It would appear, therefore, that a satisfactory procedure would be to measure a uniform number of 1000 fibres in every case,* and to accept as significantly different, tops whose mean diameters differ by more than about 3 per cent.

The question of the grading of tops with respect to an arbitrary limit for mean fineness, sometimes arises, as for instances, in the determination of limits for combing charges. Now cases will arise where the true mean of the top will lie very near the grade boundary, and in such cases a large number of measurements will have to be made to determine on which side of the boundary the true mean lies: clearly the extra labour involved in taking more measurements is not justified by the slight additional information that the top falls just above or just below a particular grade boundary line.

If then the standard number of 1,000 measurements is adhered to, "regions of uncertainty" can be fixed at the grade boundaries in the following way:—

Let a top whose true mean diameter is m, and standard deviation σ, give a sample mean of $\bar{x}$ from n measurements. Then $\bar{x}$ has a standard error $\sigma/\sqrt{n}$ and as in the previous argument the top will yield on the average, only one sample in every hundred whose mean $\bar{x}$ either exceeds $m+2{\cdot}58\ \sigma/\sqrt{n}$ or falls below $m-2{\cdot}58\ \sigma/\sqrt{n}$ that is, one in *two* hundred exceeding and one in two hundred falling below the limits. For the present purpose, however, it is better to consider the limits $m\pm2{\cdot}33\ \sigma/\sqrt{n}$ which are such that one in a hundred fall *above* and one in a hundred fall *below* the limits (or, if we replace "one in a hundred" by "one in twenty" the limits are $m\pm1{\cdot}65\sigma/\sqrt{n}$).

Let us, therefore, draw a line at distance $2{\cdot}33\sigma/\sqrt{n}$ above the grade boundary. Any top whose true mean diameter m lies on the boundary will give rise to only one sample in a hundred whose mean falls above this line, and tops whose means are less than m will give rise to even fewer. We can, therefore, consider the line to define a region of uncertainty such that any sample having mean diameter above this region is unlikely to have come from a top in the lower grade.

A similar line is drawn at distance $2{\cdot}33\sigma/\sqrt{n}$ below the grade boundary. If the sample mean falls within the uncertainty region, the quality is said to be undecided. It should be noted that we are not creating an intermediate grade, as the width of the uncertainty region can always be reduced by increasing n. Our confidence in grading is in a sense measured by the "one in a hundred" chance.† Should we be satisfied

* It is best to record these in four successive lots of 250, or five lots of 200, thus providing a check on the method.

† Note that the "one in a hundred" chance here referred to does *not* necessarily mean that we should err in grading once out of a *hundred* times on the average. To have the latter information would imply a knowledge of the *a priori* distribution of all the tops being sent for test, and this clearly is impossible to ascertain. We have circumvented this difficulty by adopting the standpoint of "fiducial" limits, cf. Fisher, *loc. cit.*

with a confidence in grading of only "one in twenty" we can narrow our uncertainty region to $\pm 1{\cdot}65\sigma/\sqrt{n}$.

SUMMARY

Previous methods of fineness measurement in wool tops are discussed and reasons given for the adoption of the present microscopic projection method. Details of experimental procedure are given in order to reduce errors of measurement to a minimum. Various sampling methods are investigated and the importance of distinguishing between "true" and "biassed" samples is stressed, in view of the correlation between length and diameter in wool tops. The method finally recommended is that of the cross-sectional sample, full details of which are given.

The final section is a statistical treatment of results obtained by this method, with special reference to (a) the significance of the difference between the sample means of two given tops, and (b) the significance of the difference of the sample mean of a top from a given grade boundary.

REFERENCES

[1] Winson, C. G. "The Examination of Selected Combed Tops." *J. Text. Inst.*, **21**, pp. T524—T545.

[2] Barker, S. G. & Winson, C. G., "Fibre Fineness and Wool Quality in Combed Tops." *J. Text. Inst.*, **22**, pp. T314-T319.

[3] Winson, C. G., "A Comparison of the Finenesses of British and Continental Standards for Combed Tops." *J. Text. Inst.*, **22**, pp. T533-T546.

[4] Küsebauch, K., Textilberichte, 1931, Vol. **12**, pp. 21 and 97.

[5] Townend, S., "Sampling and Length Analysis of Wool," *J. Text. Inst.*, **26**, pp. T130-T146.

[6] Hirst, H. R. "The Swelling of Wool Fibres." *W.I.R.A. Publication*, **17**, 1922.

Appendix I.

Objection may be raised to the fact that diameter groups as wide as 2μ are used. It is a theoretical fact that with the number of measurements actually taken, and the type of frequency distribution met with, the mean calculated from the diameters collected into frequency groups is negligibly different from that calculated, using the actual diameters themselves, as long as the number of groups is not too small. Moreover, the standard deviation σ of the grouped frequency distribution is related to the standard deviation σ_0 of the actual diameter values of the formula:

$$\sigma = \sqrt{\sigma_0^2 + w^2/12}$$

where w is the width of the group.

To illustrate this fact, the figures for a range of tops from 80's to 36's have been regrouped into groups of width 4μ, and the means calculated: the standard deviations, corrected for the extra grouping, have also been calculated and are given for comparison. The agreement is very striking, especially in the higher qualities where the number of 4μ groups is as few as 7 or 8.

Quality Number.	Mean Diameter		Standard Deviation (Corrected for Grouping)	
	4μ Groups.	2μ Groups.	4μ Groups.	2μ Groups.
36	38·61	38·66	10·07	10·06
40	38·25	38·25	9·09	9·12
44	36·33	36·40	10·50	10·48
46	34·25	34·31	9·17	9·21
48	32·52	32·54	8·20	8·17
50	30·07	30·11	7·76	7·74
56	26·64	26·66	7·26	7·24
58	24·79	24·72	6·16	6·18
60	23·53	23·49	5·71	5·68
64	20·99	20·92	4·22	4·25
70	19·58	19·53	3·90	3·92
80	19·02	18·90	3·91	3·95

Appendix II.

Let f_{ld} be the proportion of fibres in the top, of length l and diameter d.

The true mean diameter is

$$D_t = /\Sigma f_{ld}\cdot d$$

summed over all l and d while the length biassed mean diameter is

$$D_l = \Sigma f_{ld}\cdot dl/\Sigma f_{ld}\cdot l = \Sigma f_{ld}\cdot dl/L_t$$

where L_t is the true mean length. This may be written

$$D_l = \frac{\Sigma f_{ld}\,(d-D_t)(l-L_t) + D_tL_t}{L_t}$$

$$= D_t + /r\,\sigma_d\cdot\sigma_l^{\prime}/L_t$$

where $r = \dfrac{\Sigma f_{ld}\,(d-D_t)(l-L_t)}{\sqrt{\Sigma f_{ld}(d-D_t)^2\,\Sigma f_{ld}(l-L_t)^2}}$

$\sigma_d = \Sigma f_{ld}(d-D_t)^2$

$\sigma_d = \Sigma f_{ld}(l-L_t)^2$

It may also be written in another form.

$$D_l = D_t + \frac{\Sigma f_{ld}(d-D_t)(l-L_t)}{\Sigma f_{ld}(l-L_t)^2}\cdot\frac{\Sigma f_{ld}(l-L_t)^2}{L_t}$$

$$= D_t + b_l\left[\frac{\Sigma f_{ld}\cdot l^2}{\Sigma f_{ld}\cdot l} - L_t\right]$$

i.e., $D_l - D_t = b_l(L_l - L_t)$

Where $L_l = \dfrac{\Sigma f_{ld}l^2}{\Sigma f_{ld}l}.$ is the length biassed mean length

and $b_l = \dfrac{\Sigma l_d(d-D_t)(l-L_t)}{\Sigma f_{ld}(l-L_t)^2}$ is the regression of diameter on length.

Received 4/5/37

13—A COMPARATIVE EXAMINATION OF METHODS OF ANALYSIS OF WOOL FOR FIBRE DIAMETER AND LENGTH

Part II—The Analysis of Raw Wool for Fibre-Fineness

By A. B. WILDMAN AND H. E. DANIELS.
(Wool Industries Research Association.)

In this section of the paper a technique is described by which the measurement of fibre-fineness by the optical method can be carried out on raw wool. The method of sampling is based upon systematic zoning. In this operation the original sample is first divided into primary sub-samples or zones which are judged by eye to be about the same size; from each of these a very small "sheaf" of fibres is withdrawn to make up a composite sample.

Investigations have been carried out by Roberts[1] and Burns[2] proving the necessity for employing the zoning process to avoid misleading results. The following account describes the laboratory technique for treatment and measurement of the composite sample for fineness, and discusses the factors which affect the accuracy of results.

The number of primary sub-samples to be taken is an important consideration depending upon the size and degree of uniformity of the original bulk sample. No general solution of such problems can be expected, but the number of zones to fix may be determined by preliminary experiment. An adequate number of zones is reached when the variance between the mean values of the set of composite samples is reduced to approach that expected from the measurements *within* the sample. This work has been done, for example, on a South African Cape Merino fleece (divided into three parts) and it has been found that, for each part, sixteen primary sub-samples or zones fulfil the above conditions.

For a comparatively small original sample, such as would be taken from the living sheep, the problem is simpler because a number of primary sub-samples can be taken such that they are extremely small, consisting of only a few hundred fibres, and so preclude the possibility of error. For such a sample weighing approximately 0·5 to 1·5 gms., the number of primary zones would ordinarily be eight.

Preparation of the Sample

1. The composite sample, the component sub-samples of which still retain their separate identities, is washed in three changes of benzene warmed to 40° C., and is squeezed between each change. Water should not be employed for washing. The sample is now allowed to condition to room atmosphere for several hours. A number of such samples can, of course, be prepared in successive lots, in order that the work be not delayed, thus ensuring a supply of samples at the final stage ready for actual measurement.

2. A very small sheaf of fibres is then withdrawn from each of the component sub-samples: these small sheaves together form the final sample.

3. In order that the actual diameter measurements shall be representative of all the various thicknesses *along the length of each fibre* in the sample, there must be a mixing in relation to this factor. This condition is secured by cutting up this final sample into small portions from base to tip over a card with a smooth black surface. Since the number of pieces from a given fibre is proportional to its length, the method gives what is really a length-biassed

sample. To cut the sample, the wool is slipped within the fold of a small piece of foolscap paper, and paper and wool are cut together (see Fig. 1 (a)).

Each cut is made about 1 mm. below the preceding cut. It is important, for reasons stated later, to make these cuts close together, so that the resultant pieces of fibre are very short. The pieces of cut paper should not be completely severed, ensuring easy removal from the pieces and fibres (vide Fig. 1 (a)). The paper is then tapped to shake off any portions of fibres which may still adhere.

4. All these small pieces of fibre are tapped into a wide jar, containing cedar oil to a depth of about 2 cm. The type of jar used is illustrated in Fig. 1 (b) and has an internal diameter of approximately 7½ cm. This size of jar has proved satisfactory (see later section of this account), whereas, if a much narrower jar is used, there is a great danger of obtaining misleading results.

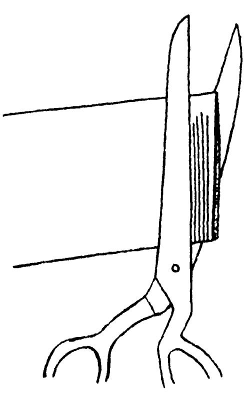


Fig. 1 (a).

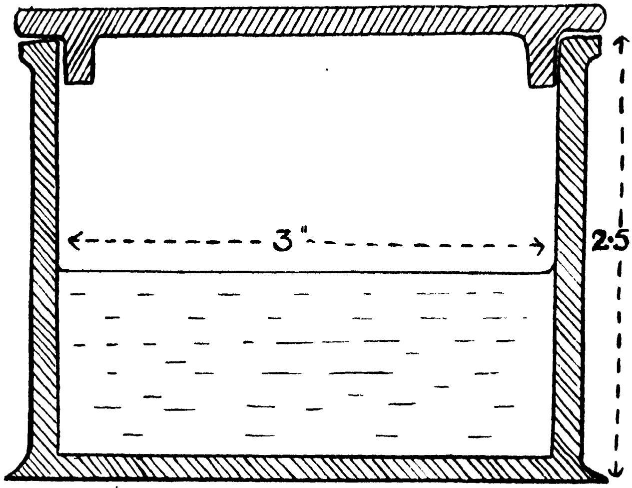


Fig. 1 (b).

5. The pieces of fibre are shaken vigorously in the oil until they are thoroughly mixed in the form of a fine suspension. This and subsequent steps in the method are similar to those used in the analysis of tops for fineness at Torridon and approved by the International Wool Textile Organisation.

6. The pieces are allowed to settle to the bottom of the jar. If the resultant sediment is rather deep, this is an indication that the final composite sample was too large and probably was not cut into fine enough pieces.

7. A portion of the sediment is withdrawn by a small spatula with a fine edge, which is inserted at one side of the jar until the bottom is reached, pushed along the diameter of the bottom and withdrawn up the opposite side. If the amount withdrawn is too small to cover the microscope slide on which it is to be mounted, a further portion may be withdrawn from the jar in a similar manner. It is essential that no *selection* should be made from any particular part of the jar, for example, the fibre-pieces must not be withdrawn from near the edges of the jar only.

8. These portions are teased out in cedar oil on a microscope slide, covered by another slide and mounted in a projector giving a magnified (× 500) image of the fibre-pieces. Actual measurements are made by using

a transparent rule and calculations made as described elsewhere.[3] See also Part 1 of this paper.

Reasons for Employing the Technique Described.

When the projection method was first used for measuring fibre diameter in raw wool, a rather narrow jar, only about 3½ cm. internal diameter and 10 cm. deep, was used to contain the fibre suspension ; moreover, the composite sample was cut into sections often 2 mm. or more deep. When certain samples were prepared in this way, it was found that on attempting to withdraw a portion of the sediment, a whole mass of felted fibres was extracted and it was suspected that this was not a true sample of the jar's contents. However, a fineness determination was made on this mass and also several other determinations were made on portions extracted from the residue.

Table I is an example of the kind of results obtained.

Table I

	Mean Diameter (μ)	Standard Deviation.
First Portion extracted ..	19·76	± 3·14
Further Portions extracted from residue —1 ..	21·36	± 3·60
—2 ..	20·58	± 3·46
—3 ..	20·84	± 3·74

With the suspension prepared in this way, the first portion abstracted has a mean fibre-diameter which is significantly lower than the mean diameters of succeeding portions taken from the same jar. Here the first portion is clearly biassed in favour of the finer pieces of fibre. This may be due to the finer fibres felting more readily than the coarser ones. Again, determinations were made on samples (a) cut into not very fine pieces and in a narrow jar, and (b) cut into fine pieces and in a wide jar. It was found that values obtained from (a) were always significantly lower than values

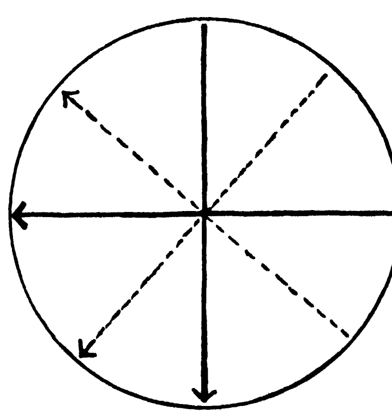


Fig. 2.

obtained from (b). Measurements from samples treated as in (a) were biassed therefore in favour of the finer fibres and were not representative of the contents of the jar.

Having decided then to use the wider jar, the following tests were made to see in what way the portions for measurement should be extracted. From each jar, portions were taken in the following two ways (*vide* Fig. 2).

(a) The spatula pushed across the bottom in two directions at right angles.

(b) Two similar strokes made at right angles to each other and also between the strokes made in (a).

In Fig. 2, the directions of the strokes are shown, the dotted lines indicating the strokes made as in (b).

Results of these pairs of experiments are given in Table II.

Table II

		Mean Diameter (μ)	Standard Deviation.	't'
8 *zones*	1(a)	21·14	3·88	0·30
	(b)	21·06	3·62	
	2(a)	20·76	3·48	0·28
	(b)	20·84	3·64	
	3(a)	21·06	4·16	0·65
	(b)	21·24	3·70	
16 *zones*	1(a)	21·42	3·50	1·29
	(b)	21·06	3·82	
	2(a)	21·10	3·70	0·44
	(b)	20·98	3·54	
	3(a)	21·20	3·96	0·45
	(b)	21·08	3·62	
	4(a)	20·76	3·92	2·06*
	(b)	21·32	4·14	
	5(a)	20·98	3·28	0·76
	(b)	21·20	3·54	
	6(a)	21·00	3·90	0·19
	(b)	21·06	3·82	
	7(a)	21·06	3·38	0·50
	(b)	20·90	3·46	
	8(a)	21·26	3·50	0·69
	(b)	21·46	3·64	

Using Fisher's table of values for " t " these pairs of results were tested for statistical significance. In this series of eight pairs of results (16 zones, Table II), the mean diameter as obtained in the manner (a) above was not significantly different from that obtained in (b) except for the one pair of results marked with an asterisk (Table II). In this case, the value of " t " is 2·06 and would seem to be significant at 1 in 25. But it must be remembered that the chance of at least one value of " t " greater than 2·06 occurring in such a group of eight pairs is $1-(\frac{24}{25})^8 = \cdot 28$, that is, rather more than one group of 8 out of every four such groups would contain at least one value of " t " exceeding 2·06 by pure chance. The occurrence of one such value in this set of eight is thus not unreasonable. We conclude that the portions can be taken from the jar in the above manner with confidence. This work indicates that the procedure described in the first part of the article can be applied to a sample of raw wool with the confident expectation that reliable and representative results will be obtained.

REFERENCES

[1] Roberts, J. A. F. *J. Text. Inst.*, **21**, T127–T164, 1930.
[2] Burns, R. H. Univ. Wyoming Agric. Expt. Sta. Bull. 204.
[3] Wildman, A. B. *J. Text. Inst.* **27**, P181–P196, 1936. And references quoted in this paper.

Received 4/5/37

Correspondence

A REVIEW OF TESTING INSTRUMENTS AND AN IMPROVED RECORDING FIBRE TESTER

To the Editor.

SIR,

As a member of the Textile Institute I beg to be allowed to make some remarks regarding the publication in the May issue of the *Journal* by Messrs. G. Osumi and E. Kato of Tokyo under the title, " A Review of Testing Instruments and an improved Recording Fibre Tester."

I fully appreciate the very careful and exact manner in which the authors have described all the known single fibre testers. But I am not in agreement with the authors as regards their requirements made on the top of page T140.

By the first stipulation, that the apparatus must be " free from the effect of friction " the fourth condition, that " it must be simple in both making and handling " is made impossible.

I have now more than fifteen years' experience with single fibre testing and may say that the apparatus constructed on the balance principle gives the best and most accurate results, because the pull on the fibre under test is exerted by a suspended part of the apparatus instead of a fixed member. The proof of the good quality of the Krais-Keyl apparatus (which is illustrated and described by the authors on pp. T130-T131) is that 125 such testers have been made and sold throughout the textile world. The type shown is the old one of the year 1920, but since then a number of improvements have been added, such as electric movement, loading and unloading device, registration of load by burette or stopwatch, testing of wet fibres, testing at different humidities, and, the reduction of friction to a minimum, such that one drop of water (about 0·05 g.) corresponds to about 1·5 cm. on the sooted paper on which the elongation is recorded. This gives a sensitiveness of ·0017 g., since half millimetres can easily be measured on the paper. Friction in the Krais-Keyl apparatus is thus negligible.

(*Signed*) PAUL KRAIS.

Dresden.

17/6/37.

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

14—A NOTE ON THE AGEING OF WOOL FABRICS

By W. T. Liu and J. B. Speakman
(Textile Chemistry Laboratory, Leeds University)

The changes in strength experienced by wool fabrics in successive finishing processes have been studied by many observers, including Midgley, Wilkinson and Law, and Brauckmeyer. In particular, Wilkinson and Law,[1] discussing the loss of strength which occurs when woollen fabrics are scoured, give the following data for cloth woven with 28 ends and picks per inch from 10 skeins yarn having a strength of 24·1 ozs.

Number of Threads in Test Sample.		Stage of Finishing.	Breaking Load (lbs.)	
Warp.	Weft.		Warp.	Weft.
199	189	Greasy	375	372
219	194	Scoured	342	257

The strength measurements were made on strips of cloth 6⅝ inches wide, and when the data were corrected for differences in the number of ends or picks, the strength of the scoured cloth, expressed as a percentage of the greasy strength, was 83 per cent. in the warp and 67·4 per cent. in the weft. The loss of strength, which is greater with woollens than worsteds, was regarded as being due to the action of the squeeze rollers in disturbing and disarranging the fibres in the yarns, the weft suffering more than the warp because " the mechanical action of the rollers is more severe on threads lying transversely to the line of motion—such threads suffer more diverse stresses of a torsional, etc., kind." Support for these conclusions is to be found in Brauckmeyer's more recent results[2] for a woollen fabric :—

Stage of Finishing.	Warp.		Weft.	
	Strength. (kgms.)	Extensibility (%)	Strength (kgms.)	Extensibility (%)
Greasy	48·0	22·1	46·0	24·4
Scoured	41·6	22·4	36·3	28·3

The decrease in strength of the weft is again greater than that of the warp, but the difference is not so great as in Wilkinson and Law's experiments. Although Brauckmeyer has attributed the fall in strength, in part, to the fact that the wool was dyed under relatively strongly acid conditions with chrome dyes, it seems probable that the main cause is disarrangement of the fibres.

So far as we have been able to discover, the loss of strength which occurs in scouring has never been regarded as other than irreversible, although reversibility would be consistent with the elasticity of the wool fibre. During the course of another investigation, however, we have discovered that scoured fabrics increase slowly in strength on standing. The phenomenon is receiving detailed investigation, but an advance statement of the original observations seems to be justified in view of their interest in relation to textile testing as well as finishing.

EXPERIMENTAL

Cloth Manufacture

As previously indicated, the gradual increase in the strength of scoured fabrics was discovered accidentally during the course of another investigation, for which the following two cloths had been made :—

(1) 56's Southdown wool

Spinning. 16/12/35. The yarns from top and bottom condenser bobbins differed considerably in count and were kept separate. Five cops of each kind of yarn were retained for testing purposes, strength measurements being made on 18-inch lengths of yarn by means of the Baer single thread tester. The data summarised in Table I refer to yarn conditioned at 65 per cent. relative humidity and 72° F.

Table I

Condenser bobbin.	Count (Y.S.)	Number of Tests.	Twist (turns per inch)	Number of Tests	Strength (ozs.)	Number of Tests
Top (weft) ...	9·38	5	8·67	50	20·7	50
Bottom (warp) ...	8·21	5	8·37	50	26·8	50

Weaving. 19/12/35—13/1/36.
Length of warp ... ... 76 yards.
Ends per inch 22
Picks per inch 22
Weave ... ... 2/2 twill.
Width at reed ... ... 70 inches.

Scouring. 16/1/36. The cloth was scoured with soda in the dolly scourer.

(2) 64's Merino noil

Spinning. 12/5/36. No tests were carried out on the yarn, which was approximately 20 Y.S. with 10·5 turns per inch.

Weaving. 18/5/36—26/5/36.
Length of warp ... ... 48 yards.
Ends per inch 36
Picks per inch 36
Weave ... ... 2/2 twill.
Width at reed ... ... 72 inches.

Scouring. 28/5/36. The piece was scoured with soda in the open-width machine, but the result was unsatisfactory. In consequence, the piece was scoured a second time with soap in the rope scourer.

Cloth Testing.

For reference purposes in connection with the main series of experiments, the cloth was tested at intervals for strength and resistance to wear. The strength measurements were made on strips about 2 inches wide, the distance between the jaws of the testing instrument being 6 inches. In the case of the Southdown cloth, the numbers of threads broken in warp and weft tests were 53 and 48, respectively. The corresponding numbers for the merino fabric were 88 and 76. Wearing tests were carried out by subjecting an 8-inch square of cloth, mounted on a horizontal table revolving at the rate of 2 r.p.m., to the abrasive action of a weighted carborundum block making 88 complete strokes per minute. The number of strokes needed to produce a hole in the cloth was measured, but no great accuracy or significance is claimed for the results. In all cases, the fabrics were conditioned for two days at 65 per cent. relative humidity and 72° F., before being cut into the

required form for testing, followed by a further two days before actual examination. It should, however, be understood that the pieces from which samples were removed at intervals for testing, were kept in a room subject to normal variations in temperature and humidity. In the light of subsequent knowledge concerning the changes taking place in scoured fabrics during storage, this failure to store the pieces in the humidity room was, of course, a mistake, but no need for controlled storage arose in connection with the main series of experiments for which the fabrics were intended.

Results.

The results of the strength measurements and wearing tests are given in full in Table II.

Table II

Cloth.	Storage Time (days after scouring)	Breaking Load (kg.)		Wearing Test (Number of strokes)
		Warp	Weft	
Southdown	13	33·8	21·6	—
		35·2	24·0	—
		33·0	24·0	—
		33·0	22·5	—
		32·5	24·9	—
Average Values ...	... ...	33·5	23·4	—
	39	33·8	28·0	1,947
		36·1	28·0	1,609
		32·9	27·4	—
		36·1	28·6	—
		32·9	25·6	—
Average Values ...	... ...	34·4	27·5	1,778
	61	34·7	31·1	2,381
		36·1	29·5	2,708
		36·1	26·0	—
		34·6	28·0	—
		34·6	28·8	—
Average Values ...	... ...	35·2	28·7	2,545
	85	39·5	30·5	3,089
		41·9	30·0	3,499
		40·8	30·4	—
		39·5	31·1	—
		38·5	30·4	—
Average Values ...	... ...	40·0	30·5	3,294
Merino	56	24·2	20·8	2,922
		24·2	20·0	2,392
		24·2	21·8	—
		24·2	20·8	—
		24·2	20·0	—
Average Values ...	... ...	24·2	20·7	2,657
	166	27·1	23·2	3,697
		27·5	23·2	3,585
		27·1	24·0	—
		27·1	24·0	—
		27·9	24·8	—
Average Values ...	... ...	27·3	23·8	3,641

DISCUSSION

The preceding results give a clear indication of the fact that scoured woollen fabrics undergo a striking increase in strength and resistance to wear during storage at ordinary temperatures and humidities. Over a period of seventy-two days the increase in strength of the Southdown cloth is 19·4 per cent. in the warp and 30·3 per cent. in the weft ; and in the case of the merino cloth the increase, over a period of 110 days, is 12·8 per cent. in the warp and 14·9 per cent. in the weft. With both cloths, the gain in strength is greater in the weft than in the warp, suggesting that the increased strength after storage is due merely to the rearrangement of fibres which had been disturbed by the mechanical action of the squeeze rollers of the rope scourer. In this connection, it is interesting to note that the Southdown cloth suffered considerable loss in strength during scouring : assuming no gain in strength from the weave, the warp and weft strengths of the test pieces, calculated from the yarn strengths given in Table I, should be 40·3 and 28·2 kgms., respectively, whereas the observed strengths, after thirteen days' storage, were 33·5 and 23·4 kgms. On the other hand, the observed strengths after eighty-five days' storage are close to the calculated strengths, and although the latter are too small, it seems probable that the loss of strength during scouring may be recovered fairly completely during storage. Although the rate of recovery at ordinary humidities is small, it should be much more rapid at high humidities if, as seems probable, recovery is associated with the elasticity of the wool fibre. In general, therefore, the results quoted in this paper give point to the trade opinion that it is advisable to allow wool fabrics a rest between successive finishing processes. Finally, in any series of experiments where scoured fabrics are subjected to a variety of treatments, the effect of the latter on such properties as strength and resistance to wear, must be determined by reference to an untreated fabric of the same age and history as the treated.

CONCLUSION

The loss in strength which woollen fabrics undergo in scouring processes is slowly recovered during storage at ordinary temperatures and humidities. It seems probable that the recovery is due to the elasticity of the wool fibre, and is associated with the rearrangement of fibres which were disturbed by the mechanical action of the squeeze rollers of the rope scourer. The phenomenon gives point to the trade opinion that wool fabrics should be allowed a rest between successive finishing processes, and emphasises the need for using untreated fabric of the same age and history as the treated, for reference purposes in experiments intended to determine the effect of various treatments on the properties of scoured fabrics.

REFERENCES

[1] J. Leeds Univ. Text. Students' Association, 1914-15, **4**, 77 ; Schofield, *Finishing of Wool Goods*, 1935, pp. 292, 340.
[2] Brauckmeyer. *Melliand Textilber.*, 1936, **17**, 407, 482.

Received 8/3/37.

15—A NEW METHOD AND EQUIPMENT FOR MAKING SMALL WOVEN SAMPLES*

Part I—The Preparation of the Warp

By H. Boffey, R. McK. Kilgour and J. A. Matthew.

INTRODUCTION AND SUMMARY

In practically all the branches of the textile industry the manufacture of sample lengths of cloth is an important feature of the work. By weaving small trial pieces it is first of all possible to find out in actual fact how, for example, a certain cloth design will appear in yarns of a certain type, whether or not a colour combination will be effective, how to a certain extent a given cloth structure " handles " when made from particular yarns, and so on. Having chosen from amongst the small samples those which are particularly attractive or desirable from one point of view or another, it is then possible to go ahead either with direct production or with larger samples for cutting and distribution to the sales organisation for the purpose of obtaining orders for the cloth. In a more limited field, sample making in a research establishment has its uses in providing for testing purposes small pieces with some specific features of yarn or cloth construction. From a commercial point of view it is desirable that samples should be made from a small amount of yarn, in a reasonably short time, and with little disturbance to ordinary factory routine. The usual methods of making samples in the linen trade involve the beaming of a short length of warp either by using a warping mill or by the ordinary practice for long warps, or the tying-in of the sample warps to ordinary warps in an already existing sett in the loom. The first procedure which is, in a way, ordinary practice abbreviated obviously requires a fairly considerable quantity of yarn and of time, and the second method suffers from disadvantages in that a warp of the required sett must be to hand and also be drawn-in to the same draft as that of the sample. The usefulness of the latter method is largely limited to samples of plain weave where colour combinations are being tried out or fancy yarns are being used. It would appear that an equipment for making quite small samples in a considerable variety of designs would fulfil a very useful purpose. These small pieces could be of such a size, say one foot square, as to give in most cases a very good impression of appearance and " handle " ; they would suffer from a slight disadvantage in that it would be difficult to give them a representative finish, but on the whole it should be possible to narrow down a wide field of designs quickly, and proceed to the manufacture of the more promising ones in larger sample pieces by the present standard methods. The whole essence of such an equipment for making the first small samples would be a strict economy of yarn and of time and also the avoidance during the preparation of the yarn for weaving of the use of any of the usual factory machinery or apparatus thus occasioning no interference with normal activities. Such an equipment is described in the following pages ; it

*This equipment forms the subject matter of two patent applications.

consists of three main parts, a special reel upon which the warp is wound and is drawn-in through heddles and reed at the same time, a small beam of special construction and stand for winding on the sheet of warp from the reel when the sample is to be woven in an ordinary loom, and a small loom of special construction for weaving the warp, if desired, as a continuous band after removal from the reel.

GENERAL DESCRIPTION

The yarn for warp is supplied on a single bobbin or hank if it is all of one kind or on as many bobbins or hanks as there are kinds or colours of yarn in the case of a mixed warp. An end of the yarn is threaded through the eyes of the metal heddles placed side by side in a continuous row and held in a vertical magazine. The yarn enters the bank of the heddles at the top, leaving at the bottom to pass on to a wooden reel revolving upon a horizontal axis and carrying among other things the reed which in this case is open at the top and which is placed with the open half projecting beyond the level of the outside of the reel bars. The operator rotates the reel through one revolution thereby withdrawing yarn from the supply through the bank of heddles and laying it as a single round on the reel. At some point in this rotation the movement is stopped and the lowest heddle is released from the magazine to be moved along the yarn and fitted against a selected horizontal bar of the reel with its eye on a level with the outside of that bar. Also during the revolution of the reel the yarn slips into the correct space between two reed dents. In this way the yarn is warped and drawn-in through heddles and reed in the one operation. The particular bar in the reel against which the released heddle is placed is determined by the draft of the pattern about to be woven upon this sample warp. All heddles associated with the same leaf or shaft during weaving are attached to the same bar of the reel, and when all the warp has been reeled metal strips or laths are threaded through the loops at the top and bottom of each group of heddles to complete the shafts. In order to save the operator any worry regarding the correct reel bar against which to place each heddle after release, an arrangement employing selecting levers and the ordinary dobby cylinder and lags is employed behind the reel. These lags are pegged according to the draft of the pattern to be woven and during each revolution of the reel, the latter is automatically stopped with the correct bar uppermost to receive the next heddle. The magazine of heddles is given a slow sideways traverse during the rotation of the reel so that the yarn is laid upon the latter in the form of a spiral of very fine pitch. The rate of traverse of the magazine is determined by the sett of the warp, and depending upon the number of ends which are to work in each split of the reed, the yarn is automatically fed into a split for two or three, etc., complete revolutions of the reel after which it is fed into the next split for a further two or three, etc., revolutions of the reel, and so on progressively. The laying of each lap of yarn into the correct reed split is accomplished by the use of a needle or finger which is carried across the reel on a traversing screw, and is pressed between successive reed wires to form a V-shaped opening at the top of the reed, which persists between any two wires for as many revolutions of the reel as it is desired to place warp ends in a split. If the same yarn for warp is used throughout the single supply is sufficient ; if various warp ends are required it is necessary at the correct moment to substitute one bobbin for another, break the first

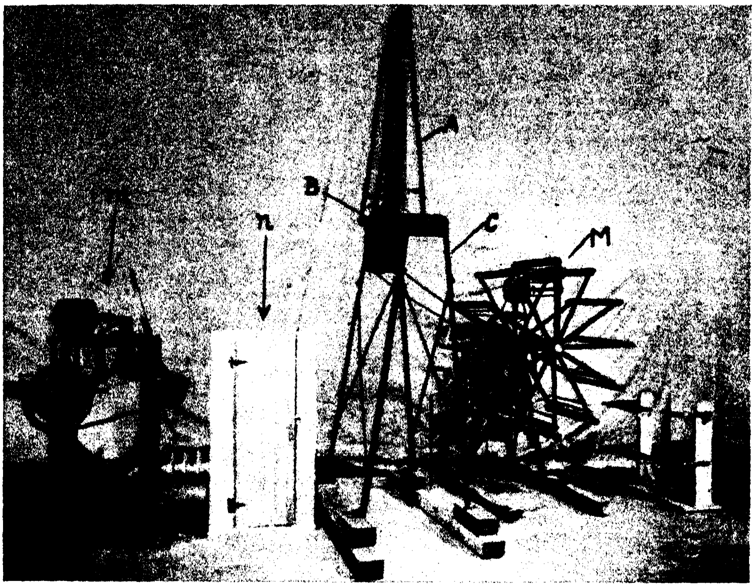


Fig. 1.

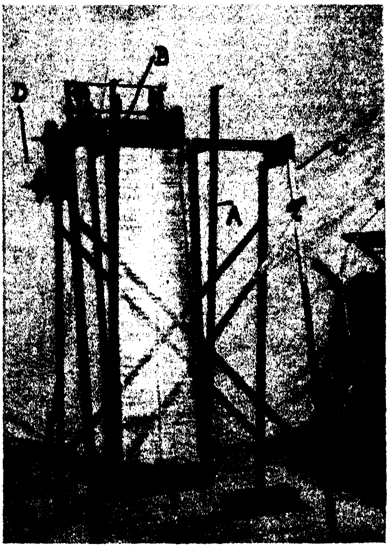


Fig. 2

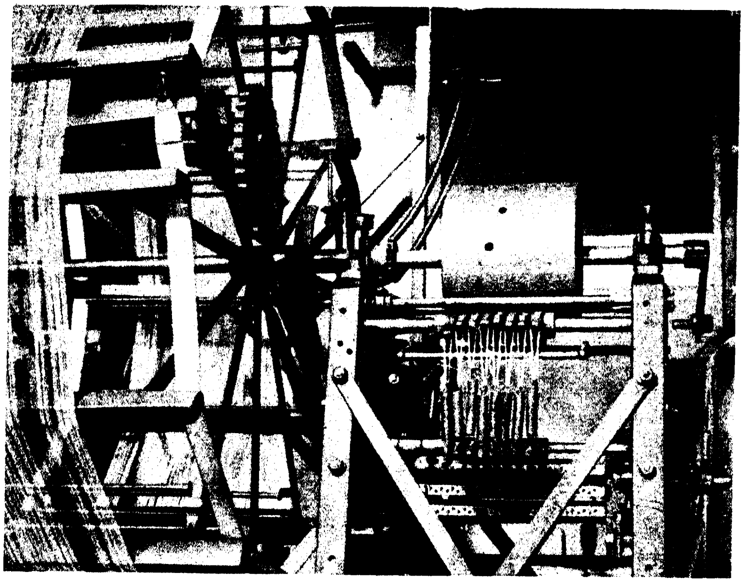


Fig. 5

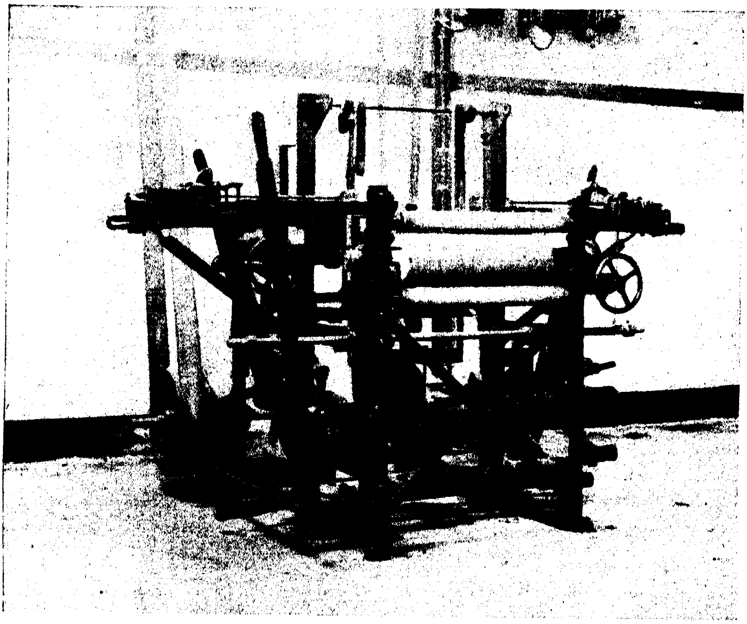


Fig. 1 (Part II)

yarn and tie on the second and so on. Also if it is required to dress the yarn with size during reeling, this can be accomplished by interposing a simple dressing unit between the supply bobbin or hank and the heddle magazine. When the whole of the warp has been reeled, two narrow clamping pieces are fastened across the yarn to prevent any unwinding of the latter during transit to the loom, metal strips are threaded through the end loops of the heddles, a cord is placed round the top half of the reed above the yarn, and the warp is ready for doffing. Two methods of dealing with the reeled warp are now available; in the first the yarn is left as a continuous band, the reel is slackened a little to allow the heddle shafts and reed to be gathered together and is then fully collapsed to allow the circular warp to be taken off endways. This warp complete with heddles and reed is then carried to a special type of loom the main feature of which is the absence of a fixed slay, the shuttle race being formed and broken during each pick cycle. This type of construction allows the circular warp to be placed directly into the loom from above and woven "round." The other method of dealing with the yarn after preparation on the reel is to place the two clamping pieces close together in front of the reed and cut the sheet of yarn across between the two. The reel is then rotated slightly and one clamp carrying the ends of yarn placed in a slot inside a special small beam mounted upon supports near the reel. These supports also carry a metal frame with suitable slots so that as the beam is slowly turned, winding up the yarn from the reel, each heddle shaft as it comes round on the latter is detached from it and placed upon the frame, all the shafts and also the reed and second clamp being finally collected there. The beam of yarn together with heddles, reed and clamp are then carried to an ordinary loom which has been slightly modified to cope with the sample warp; the weaving is thereafter practically the same as for a normal large beam.

The photograph in Fig. 1 shows the whole of the reeling apparatus, the components from left to right being the dressing machine, the yarn-drying box, the heddle magazine, the reel and the beam stand. In the photograph in Fig. 2 is a nearer view of the heddle magazine, showing the top half dropped back for loading purposes, as will be explained later. For the purpose of taking this latter photograph the magazine was turned out of its normal position through a right angle in an anti-clockwise direction.

The portion of this paper which follows is devoted to a detailed description of the preparation of the sample warp for weaving; Part II which will follow as another communication will describe the new small loom and the modifications to an ordinary loom for the weaving of the sample warp prepared as above.

The Heddle Magazine and Heddle Release Gear.

The metal heddles used in this work are standard except perhaps that the centre eye is set at a slightly narrower angle to the end loops than usual; this facilitates movement in the magazine. The latter consists of a vertical framework A (see photograph Fig. 1) slightly wider than the length of a heddle and about four feet high, supported on a board or table B whose base is itself supported upon two smooth, parallel, horizontal rods fixed in a stout frame C at a height of about five feet from the ground. Between the two smooth rods and parallel to them is a screwed rod which is threaded through a nut fixed to table B and also has a smooth projection beyond the framework C. Upon this projection is keyed a cog-wheel which engages

an intermediate which itself engages a third cog-wheel fixed upon a small counter-shaft to which is also keyed a chain sprocket-wheel; this system is shown at D in the photograph, Fig. 2. A drive is obtained via a chain from the reel to the latter sprocket-wheel (this chain drive is clearly seen in the photograph, Fig. 5), and by rotating the screwed rod below the table B gives a traverse motion to the magazine. The purpose of the intermediate cog-wheel which can be swung into position on a quadrant slot centred about the axis of the counter-shaft is to allow the top pinion on the screwed rod to be changed for varying the rate of traverse of the magazine to suit the sett of the warp being prepared, and all three cog-wheels are standard loom take-up change-wheels, so that in a factory use can be made of the extensive range of the latter kept in stock. Reference should now be made to the detailed drawings of the lower portions of the magazine shown in Figs. 3a, 3b, and 3c, Fig. 3a being the front view and Figs. 3b and 3c end views. Fixed to the top of the magazine frame and stretching almost

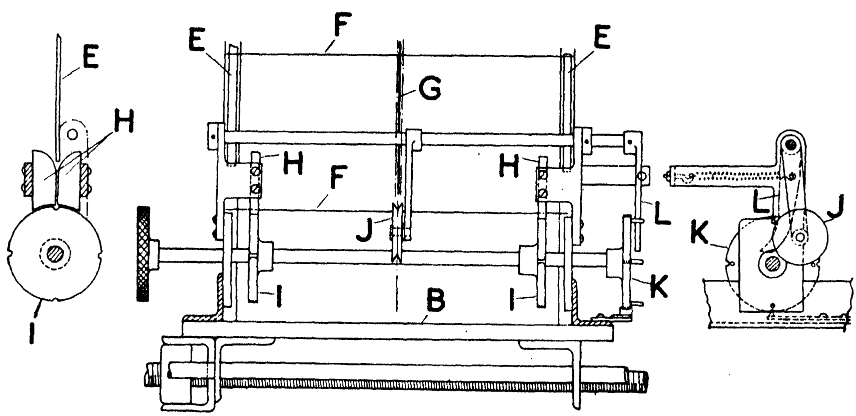


Fig. 3b. Fig. 3a. Fig. 3c.

to the bottom are two vertical strips E whose lower ends are free and upon these strips are threaded the end loops of the heddles F. The centre eyes of the heddles are also threaded upon a stout wire G also fixed at the top and free at the bottom. The heddles are thus arranged in a continuous vertical bank and are able to slide freely down the side strips and centre wire as the lower ones are continually being removed in a manner about to be described. The bottom ends of strips E are situated in the same vertical plane and slightly to the outside of two slots formed by pieces H (clearly shown in Fig. 3b) so that a heddle coming off the strips falls naturally into the slots. At the bases of the slot-pieces H which are shaped to the arc of a circle are two similar wheels I with small grooves in the rims as shown, these grooves being just large enough to take a single heddle wire. The wheels I are fixed to a shaft set in bearings in the framework and capable of being rotated by the operator by means of a milled hand-wheel fixed to its outer end. The settings of the two wheels I upon the shaft and the clearance between them and the concentric bases of the slot-pieces H above are such that a single heddle can fall from the slots into two grooves, one in each wheel, and be carried round with the wheels when the latter are rotated by the operator. The heddle thus released from the magazine can then be

moved by hand along the warp yarn to the reel. In order to guide the yarn as smoothly as possible in its passage through the bank of heddles a pulley on a fixed axis is placed at the top of the magazine where the yarn enters the heddles and a second pulley (shown at J in Figs. 3a and 3c) is situated at the bottom of the heddle bank just alongside and below the centre eye of the lowest heddle. The yarn leaving the magazine runs round this pulley J making approximately a right angle bend. The position of pulley J is necessarily such that it lies in the direct path of a heddle which is being released from the magazine. To overcome this difficulty it is arranged to lift the pulley out of the way of the off-coming heddle (the yarn being stationary meantime due to the reel being stopped) and to lower it into its normal "running" position immediately the heddle has been removed by the operator. This is accomplished by having the axis of the pulley J mounted on the end of an arm fixed to a shaft parallel to and above the main shaft turned by the operator. Fixed upon the far end of the latter shaft is a grooved wheel K exactly similar to those I already described save for the addition of four small pegs in its outer face next to the grooves in the rim (these details are clearly shown in Figs. 3a and 3c). Against each of these pegs in turn is spring-pressed a curved arm L which is fastened to the same upper shaft which carries the arm supporting the pulley J. It is clear that as the main shaft is turned (clockwise in Fig. 3c) the curved arm L will be pushed to the right and cause the pulley J to be raised; at a certain point the peg in operation is turned past the end of the curved arm and the rocking system returns to its normal position under the action of the return spring. The purpose of the grooves in the rim of the wheel K is to position the whole system carried by the main shaft; a V-shaped point sprung against the rim (see Fig. 3c) engages a groove at each quarter turn of the main shaft, and at each such position a groove in both wheels I is placed exactly as shown in Fig. 3b ready to receive a heddle from the bank above.

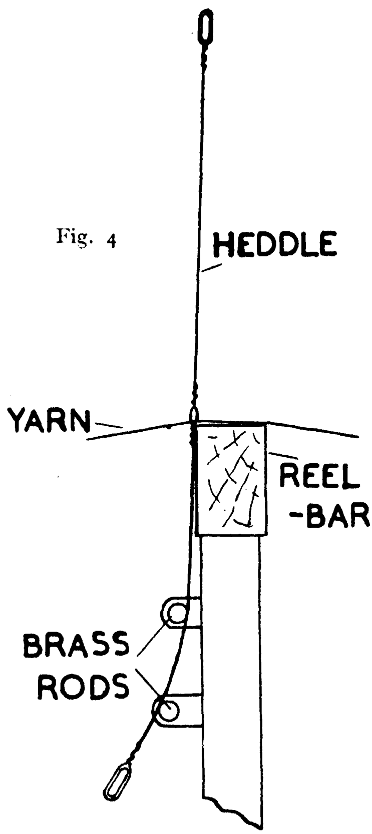
The filling of a magazine with heddles is quite an easy task. The framework A is attached to the table B in such a way that it can be swung back and down out of the vertical position, the top being now near the floor and the free ends of side-strips E and centre-wire G opens for the operator to feed on the heddles which slide down the strips and wire until the bank is filled up (see the photograph Fig. 2). After this, small split-pins are put into the open ends of the strips to keep the heddles in place temporarily and the whole frame swung back into the upright position ready for reeling. The free end of the centre wire G contains a small eye and during the filling of magazine a smooth, strong, fine cord is fastened to this eye and runs along the wire to the floor so that each heddle eye is also threaded upon this cord. Later, when the magazine is in position for reeling to begin, it is a simple matter to tie on the warp yarn to the cord above the top heddle and draw it through the heddle eyes to the bottom. The cord is also left of sufficient length that there is always a portion of it stationary in the heddle eyes during reeling so that if a breakage in the warp yarn occurs in the bank it is easy to draw through the new end of yarn and piece up.

The Reel and Reel-Positioning Mechanism

The reel (shown at M in the photograph in Fig. I) consists of a number of parallel horizontal wooden bars (in our case twelve) fixed at each end to spokes which, except in the case of one pair, are all free at their inner ends upon the central main shaft of the reel from which they radiate. The remaining

pair of spokes are fixed on this shaft and two stout tapes (or chains) are fastened one at each side to all the bars in turn so that when the circuit is complete and the tapes tight the bars are equally spaced round the circumference of the wheel. Unhooking the tapes between the "fixed" bar and the next one allows the reel to be collapsed if necessary for the purpose of doffing the completed warp. To facilitate the latter operation one end of the reel is open, the main shaft being extended at the back beyond the other end of the reel and carried in two bearings which are supported in a strong framework shown at N in Fig. I. Attached to each pair of spokes except one, and parallel to and near each wooden bar, are two thin metal rods held in small side brackets, the rod nearer the centre being fixed and the other one detachable. The arrangement of a bar and its accompanying two rods is such that it is an easy matter to place the lower half of a metal heddle against or in front of the bar, behind the first rod next to it and in front of the second rod nearer to the centre of the reel. Fig. 4 shows a side-view of the arrangement and needs no further explanation. The device for stopping

Fig. 4



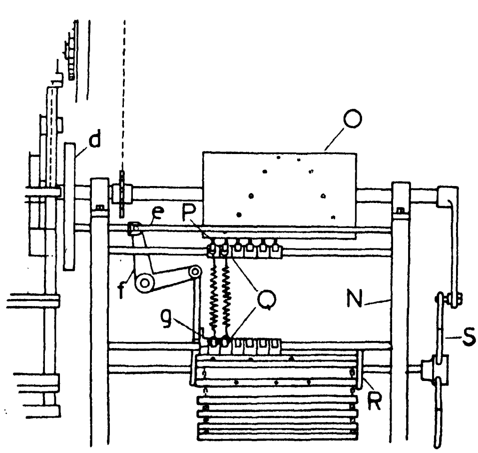


Fig. 6a.

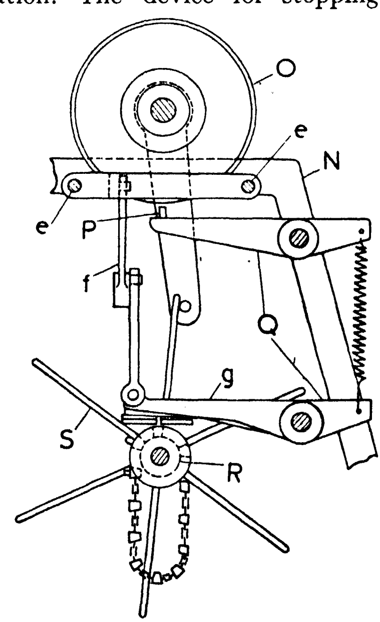


Fig. 6b.

the reel once during each revolution in a position which brings uppermost the correct bar for taking the next heddle can be seen photographically in Fig. 5 and diagrammatically in Fig. 6a (front view) and in Fig. 6b (end view). The portion of the main shaft of the reel which lies between the two bearings in the framework N carries fixed to it a metal cylinder O having small holes, one for each bar of the reel, disposed round its surface in a spiral and equidistant from each other, the angular rotation (in a plane at right angles to the shaft) from one hole to the next being equal to that between one reel bar and the next. In the path of each hole as it rotates with the cylinder is a small peg P carried on the end of the upper member of a two-lever system Q with spring connection. The corresponding end of the lower member of this system rests upon a lag cylinder R of the type used with ordinary dobby shedding, this cylinder being fixed to a counter-shaft and

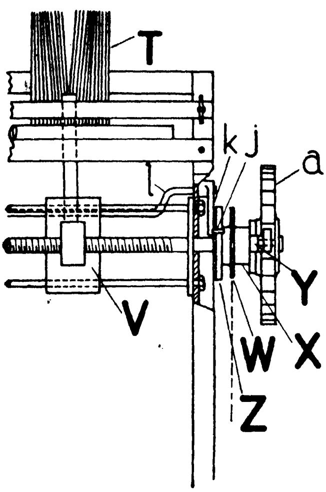


Fig. 7b.

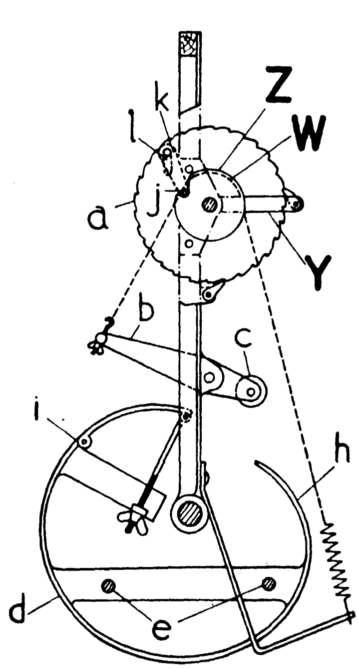


Fig. 7c.

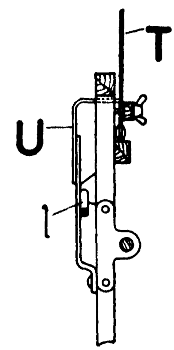


Fig. 7a.

given a rotation through a spider S fixed to the end of the counter-shaft and an arm attached to the end of the main shaft above coming against the spokes of the spider. By this means a fresh lag is presented to the end of the lower lever in system Q at each complete revolution of the reel. If the lag is pegged at this point the result is to raise the peg P in the top lever from a position just clear of the surface of the cylinder O (which it occupies when no lag peg is presented to the bottom lever) to one in which it bears hard upon the cylinder, and when the hole in the latter associated with this particular peg P comes round to it, the one goes into the other and the reel is stopped with that bar uppermost which is also associated with the hole and peg in question. To obtain what one might term automatic selection of the reel bars for heddling, it is therefore only a matter of pegging the lags

on cylinder R to suit the draft of the pattern it is desired to weave from the warp being reeled. In order to absorb the shock caused by suddenly stopping the reel by a peg P, the bar about which the upper levers of the system Q are fulcrumed is mounted upon stout leaf springs fastened to the framework N. Also a cross rod near these upper levers is connected suitably to a foot-pedal near the operator, so that when a heddle has been positioned against the reel and it is desired to rotate the latter again, the end of the lever which previously stopped the reel may be depressed, removing its peg from the cylinder hole.

The Reed-Opening Apparatus.

It was mentioned earlier that one pair of spokes supporting a reel bar are rigidly fixed to the main shaft. These are slightly stouter than the others and the bar they carry is the one not supplied with a pair of heddle supporting rods, instead they carry a second wooden bar a short distance below and to one side of the ordinary reel bar as will be clear by reference to Fig. 7a which is an enlarged side-view of this portion of the reel showing the top portion of the spokes in question. The open-topped reed T rests upon the subsidiary bar and against a smooth plane strip of iron fixed just below the reel bar being finally clamped in position by a third detachable wooden bar and bolts and wing-nuts as shown in the figure. The arrangement is such that an appreciable portion of the reed extends beyond the top of the ordinary reel bar, and it is this part which must receive the yarn during reeling. It has already been said that each single lap of yarn on the reel is laid alongside its neighbour at the distance from it required by the sett of the warp, and that in turn each split of the reed is opened out at the top to receive the yarn. This latter operation is automatically achieved by the following mechanism. (Reference should also be made now to Fig. 7b which shows a front view of a portion of the reed and Fig. 7c which shows the same end view as Fig. 7a, the lower part of the spokes and the part around the main shaft of the reel now being included, but with the reed and needle carriage cut away to disclose the details of the traversing mechanism behind.) At the point where the yarn desires to enter the reed the two reed wires concerned are forced apart by the insertion between them of the V-shaped tip of a needle U, bent as in Fig. 7a and fixed at its lower end through a springy piece to the carriage V which can slide freely upon two horizontal and parallel rods and is caused to do so by the rotation of a traversing screw threaded through a nut on the carriage V, this screwed rod being parallel to the other two slide rods and supported in bearings fixed to the two reel spokes. The operation of the opening-needle U is made up of three distinct parts, the withdrawal from the reed split, the horizontal movement to a position opposite the adjacent reed split, and its insertion into the latter. Considering first the sideways movement from split to split, this is brought about by giving to the traversing screw a definite rotation by means of a chain over a sprocket-wheel W on the end of the screw. This wheel is not a fixture on the screw shaft but is fastened to a collar X freely rotatable on the shaft, to which collar are also fixed a pawl-carrying arm Y and a cam Z. The purpose of this cam will be described shortly. The pawl on the end of arm Y engages the teeth of a ratchet-wheel *a* which is keyed to the end of the traversing screw, so that a rotation of the chain wheel W in one direction (counter-clockwise in Fig. 7c) causes a rotation of the ratchet-wheel and traversing screw and so a movement of the needle carriage. One end of the

chain which runs over the wheel W is attached to a lever *b* fulcrumed on a pin carried by a bracket bolted to the reel spoke ; the other end of the chain is connected through a coil spring to a right angle bracket also bolted to the reel spoke. The lever *b*, at the end opposite to that holding the chain, supports a small roller *c* free to revolve on a stud through the lever. Immediately behind the reel spoke and roughly speaking symmetrically disposed with respect to the main shaft of the reel in a plane at right angles to this shaft is a cam *d* whose outline is as shown in Fig. 7c. This cam has no rotational movement, only a short to-and-fro motion in a direction parallel to the main shaft, being fixed to two rods *e* which can slide freely in bearings in the framework N. (Reference should again be made here to Figs. 6a and 6b.) This to-and-fro motion of cam *d* as a whole is intermittent and is designed to bring the cam into or out of the path of the roller *c* as the latter is carried round with the reel. To this end a cross-piece joining the two slide-rods *e* is connected via a bell-crank lever *f* and link to a single-arm lever *g* fulcrumed on the same shaft as the lower levers in systems Q and like the latter actuated by pegs in the lags on the cylinder R immediately below. Thus a peg below lever *g* causes the slide-rods *e* and therefore cam *d* to move towards the reel, bringing the cam into operation with respect to the roller *c*. Following this and in the absence of a peg on the next lag turned up by the cylinder R, the rods *e* are returned outwards from the reel under the action of two compression springs against the framework N, and thus carry the cam out of the path of the roller. It is the former case which must now be considered, namely that of the cam in the path of the roller. As the reel is rotated, clockwise in Fig. 7c, this roller *c* is carried round until it bears upon the first portion of the cam (say at *h*). The latter is of such a shape that the distance of its surface from the centre of the main shaft of the reel increases continuously from the beginning above *h* round to a point *i*, at which point a further portion of the cam is hinged to the main section, and the distance between the centre and the surface of this new portion now continuously decreases at a rate which can be varied by the adjustment of a clamping screw with wing-nut as shown. The increase of radius from point *h* to point *i* causes the roller *c* to be thrust outwards and the lever *b* to be given thereby a definite rotation, resulting in a pull on the chain and a rotation of the traversing mechanism as already described. Although the slope or rate of throw of the cam is fixed, it is readily possible to alter the amount of rotation given to the lever *b* and so the amount of traverse of the reed-opening needle by moving the point *h* at which the roller first comes into contact with the cam along the surface of the latter. This is done by making use of an adjusting screw joining the end of the chain to the lever *b* and so altering the effective length of the chain and the free normal setting of the lever with respect to the main shaft of the reel. When the lever and roller are not in contact with the cam, the metal piece on the end of the chain into which the adjusting screw is threaded rests against a bracket carried by the reel spoke. The hinged portion at the leaving side of the cam is provided to allow of gradual return of the lever against its stop bracket without undue shock.

At the beginning of this discussion of the traversing mechanism for the reed-needle carriage V, mention was made of a cam Z fixed to the same collar as the chain wheel W on the end of the traversing screw. The shape of this cam can be seen clearly in Fig. 7c ; it is a complete circle except for

a notch as shown, and in this notch, when the traversing gear is not being rotated, lies a pin *j* fixed to a short arm *k* carried upon the end of a cranked rod *l* running across the reel parallel to the two rods upon which the carriage V slides and bearing against the inner face of the lower portion of the needle U (see Fig. 7a). When the pin *j* is in the notch the point of the needle presses between the two reed wires, but immediately the traversing gear starts to rotate, that is, the needle carriage starts to move sideways, the rotation of cam Z causes pin *j* to be forced outwards, and thereby the cranked portion of rod *l* presses back the needle out of contact with the reed wires, until such time as the sideways motion of the carriage has ceased and wheel W, and with it cam Z, have returned to their normal positions, whereupon pin *j* falls into the notch again and the tip of the needle is thrust between a new pair of reed wires. The position of the large traverse cam *d* is such that the whole of the operation of withdrawal of the needle tip, sideways movement of the needle, and re-insertion of the tip into the reed, is carried out while the latter is in the lower half of the revolution of the reel, so that a stationary condition has been reached and a V-shaped opening in the top of the reed is ready for presentation to the yarn as the reed moves up to its highest position. A change from this stationary condition is made, via the medium of the pegs in the " dobby " lags, once every one, two or three revolutions of the reel depending upon whether it is required to put one, two or three warp ends in a split, and so on.

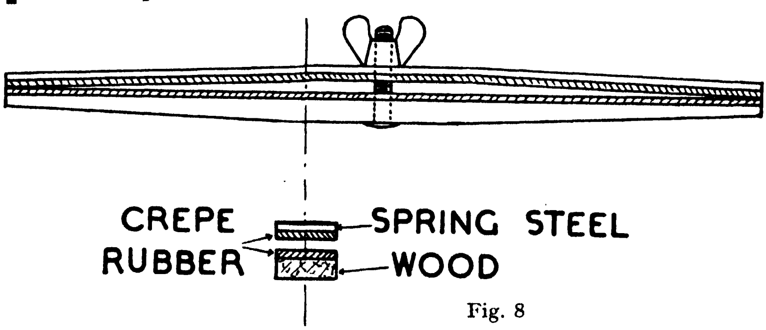


Fig. 8

It should be mentioned that in order to give to the needle carriage V the exact amount of traverse at each movement as required by the sett of the reed, it is necessary to be able to give the ratchet-wheel *a* a definite rotation which is one of a series of fractions of a complete rotation (i.e., 360°). To cover this range of fractions of 360 degrees rotation, a number of ratchet wheels with various numbers of teeth are required, but the range of wheels is not too extensive, and as they are ordinary fluting-machine ratchet-wheels (as used in a linen mill for fluting wooden spinning rollers) they are quite standard and readily obtained.

Doffing the Warp

As the operator stands working the apparatus the heddle magazine is on his left and the reel in front of him and slightly to his right. If, viewing the reel from his position, the bars are numbered in the counter-clockwise direction beginning with the first one past that which carries the reed as No. 1, then those heddles which are positioned against bar No. 1 are to form shaft No. 1, those against bar No. 2 are to form shaft No. 2, and so on in the loom. The operator aligns the top and bottom loops of all the heddles

against a bar and inserts through each row of loops a thin metal strip with a small hole at each end, into which hole is finally clipped a small ring. This procedure secures each shaft of heddles ready for transfer to the loom. When beginning the reeling the operator secured the first end of the warp yarn to a bar such as No. 10 in our case (the bar carrying the reed being No. 12) and at the end of the reeling the last end of the warp is fastened to a bar such as No. 11. Then when clamps are placed across the sheet of yarn between these two bars, the whole of the warp is secured and the loops of the two ends round the reel bars may be broken preparatory to doffing the warp. The type of clamp used to secure the yarn is illustrated in Fig. 8. It consists of two thin, narrow strips, one of wood, one of spring steel, a little longer than the width of the sheet of warp, and lined upon the inside faces with thin crêpe or corrugated rubber. To the centre of the inside face of the wooden strip, which is flat, is fixed a short bolt and there is a corresponding hole to accommodate this bolt through the centre of the other strip, which is slightly bowed, being concave with respect to the first strip. The result is that when the two are laid against each other, one upon each side of the warp, and tightened in this position by means of a wing-nut

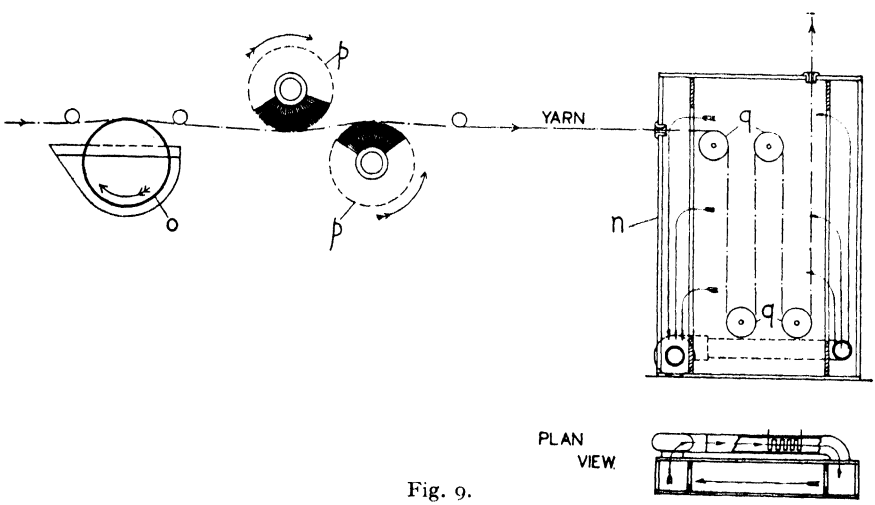


Fig. 9.

on the end of the bolt, the yarn is gripped very tightly over the whole width of warp. As was mentioned at the beginning of this paper, one such clamp is used if it is intended to weave the cloth upon the special sample loom, two if the warp is to be transferred to a modified ordinary loom. The only thing remaining to be done prior to taking the yarn from the reel is to prevent the ends from coming out of the open splits of the reed by tying a cord round the latter above the warp or securing by some other simple clamping device.

Dressing the Warp

When this reel was first made and used no particular attention was paid to dressing the warp, the rather primitive method of brushing on a mixture when the yarn was in the loom being resorted to when necessary, as in hand-loom weaving. Recently, however, a trial has been made of a method of dressing the single end of warp as it leaves the supply bobbin

to go to the heddle magazine, and quite good results have been obtained. The dressing apparatus, consisting of an impregnating unit and an air drying chamber, can be seen on the left at *m* and *n* respectively in the photograph in Fig. 1. A diagrammatic view of the arrangement is also shown in Fig. 9. The warp yarn from the supply runs below two guide rollers over the top of a flannel-covered sizing roller *o* positively driven in a trough containing the dressing mixture, this roller carrying up dressing on to the yarn as in ordinary linen dressing. The yarn then passes between two brushes *p* rotating so as to brush against the direction of travel of the yarn for the purpose of removing excess dressing and smoothing-off the surface of the yarn. The latter then passes through a guide into the drying chamber *n* which consists of a wooden box (in this case approximately a yard high, a foot wide and three inches deep) with a door at the front and an inlet and outlet for pipes at the sides. The outlet is connected by a short pipe to the intake of a small centrifugal blower driven by a direct coupled motor, and the outlet of the blower is connected to the inlet of the box by a pipe which carries a resistance unit of the type used in electric fires, consisting of a spiral wound upon a long thin, porcelain cylinder. By these means a current of hot air is circulated through the box. To the inside of the back of the latter are screwed brackets carrying four light pulleys arranged as at q in Fig. 9. The box stands upon the floor and the yarn from the dressing machine enters at the top of the left-hand side, passes round each pulley in the order shown, and leaves at the right-hand side of the top of the box to go straight up to the top of the heddle magazine. The total length of the yarn in the box at any time is somewhat greater than the circumference of the reel, so that when the latter is stopped for the positioning of a heddle once during each revolution, at least one complete lap of yarn is being dried whilst stationary in the box. This helps to give complete and fairly uniform drying of the warp.

Dimensions of the Apparatus and Operating Times

No details have been given so far of the dimensions of the reel and of the time involved in the various operations. When designing this apparatus in the first place the reel and special sample loom were considered as one complete unit, the idea being to weave the warp as a continuous band involving no cutting of the yarn on the reel; this required the embodiment in the loom of certain special features. These general considerations automatically limited to a certain extent the length and width of the warp, it being thought advisable on the grounds of ease of handling of the yarn during transfer from the reel to the loom and for the sake of the general compactness of the loom itself, to limit the length of the warp to ten feet; and it was considered doubtful if the suggestion in mind for the shuttle-race and picking mechanism on the new loom would work well for a cloth width greater than about twelve inches. Accordingly, in the model of the reel embarked upon, the circumference was fixed at ten feet and the reed space at one foot (with the allowance for the spokes, various brackets and other associated mechanism this means a length of reel bar of about 22 inches). With these dimensions the reel is quite compact and easily handled and the operator can perform the various operations at a perfectly convenient height whilst standing upon the floor. With the more recent adaptation, however, of the reel to work in conjunction with an ordinary loom slightly

modified, whereby the warp is cut and beamed, the former considerations limiting length and width of warp no longer apply, and it is possible to increase both to a certain extent. There are several factors to be borne in mind, however, if this is done. If the diameter of the reel is increased beyond a certain point it will be necessary to provide a platform for the operator, also the weight will be greater, and if in addition the width is increased, again adding to the total weight, it would probably be better to provide a third bearing for the main shaft of the reel in a stand at the side of the latter, near the operator, there being now no necessity to leave this end of the reel open for doffing purposes. Also with the present dimensions of reel, heddle, and heddle magazine the latter when full holds about six hundred heddles, or enough for one sample of $10^{\circ\circ}$ sett ; if reed spaces greater than one foot are used with the same sett of warp a refilling of the heddle magazine would be necessary during the reeling of the complete warp. These various minor difficulties, if they can be called such, are either easily surmounted or are not important enough to vitiate the usefulness of a larger reel if desired ; but a point that was raised at the beginning of this paper should be reiterated here, namely, that the general purpose of this sample making equipment is to provide quickly from a minimum quantity of yarn a small piece of cloth for inspection, before choosing from among many those worthy to be produced in larger samples on standard machinery. For these ends, it is maintained that the smaller reel now in use, which results finally in the weaving from one sample warp of a piece of cloth approximately seven feet long by one foot wide, is amply sufficient.

As regards the operating time with this equipment, the following figures may be taken as a rough guide : filling up heddle magazine with heddles, ½ hour ; reeling, 200 ends per hour, 3 hours for a sett containing 600 ends; doffing and gaiting in loom, ½ hour. Allowing therefore, for such items as aligning the magazine and reel at the start, fitting suitable pinion and ratchet-wheel, pegging lags, preparing a small quantity of dressing, winding the small amount of warp and weft required, etc., it should be quite within the capacity of an average operator to produce a sample length of cloth in about five hours.

Part II—The Weaving of the Sample

INTRODUCTION AND SUMMARY

Part I of this paper dealt with the description of a new type of reel and subsidiary mechanism for making a sample warp approximately ten feet long and one foot wide completely ready for weaving, that is to say, drawn-in through heddles and reed and dressed with a sizing mixture. It was stated that two methods of dealing with the warp after this preparation were available, one involving a special loom which weaves the yarn as a continuous circular band, the other being slightly modified standard practice on an ordinary loom. The alternative methods of weaving the sample are now described, the special loom being dealt with first.

New Loom for Weaving Continuous Sample Warp.

General Features

A general view of the special loom is shown in the photograph in Fig. 1. There is no sley of the usual type, the shuttle being positively guided upon a metal race which is made in two halves, which are carried in fixed shuttle boxes at the sides of the loom and are simultaneously inserted into the shed for the purpose of picking the shuttle and withdrawn from the shed immediately afterwards, once during each pick cycle. There is also no crankshaft as in the ordinary loom, the movement of the reed for the purpose of beating-up the weft being governed by two cams on the bottom-shaft bearing against rollers fixed to the sword arms. The lower reed support joining the two swords can be detached, leaving the whole of the centre of the loom between take-up and let-off rollers clear for the purpose of placing the continuous band of warp into position for weaving. Shedding is accomplished by means of under-tappets of longer dwell than normal and the treadles are fulcrumed on a heel-pin at the front instead of at the back of the loom. The actual picking of the shuttle across the special race mentioned above is performed by what is, in a way, a combination of the usual over- and under-pick motions. The path of the warp in the loom is described in more detail later. The taking-up of the woven cloth is done by means of a sand-roller driven through a worm-reduction gearing from a friction ratchet-wheel, itself rotated through a motion derived finally from the rocking shaft. The letting-off or forward of the warp presents in this case a different problem from the ordinary system, because in addition to a releasing of the correct amount of yarn at the back under a suitable average tension for weaving, provision has to be made for the fact that as weaving proceeds the length of the band of cloth plus yarn continuously diminishes due to take-up or corrugation of the warp in the fabric. Small temples of the simple roller type are used to keep the cloth out to width. Provision is made for stopping the reed and sword arms in the fully back position if the shuttle does not box properly. This is very necessary, because a failure of the two halves of the moveable sley and the suttle to go fully home into the boxes would result in serious damage if the reed and swords were to come forward under these conditions. When a stoppage of this nature occurs, the loom handle is not knocked off, but a slipping device in the drive comes into operation. This is very easily arranged since a single bottom-shaft carries all shedding tappets, beating-up cams, sley actuating cam and picking tappets,

and this is driven by a simple chain drive from one end of a counter-shaft low down at the back of the loom, which is driven through a belt from an overhead shaft. A fast and loose pulley system on the counter-shaft, coupled *via* a belt-fork to the starting handle, provides the customary method of setting-on and stopping the loom.

The various features of the loom will now be described separately in greater detail.

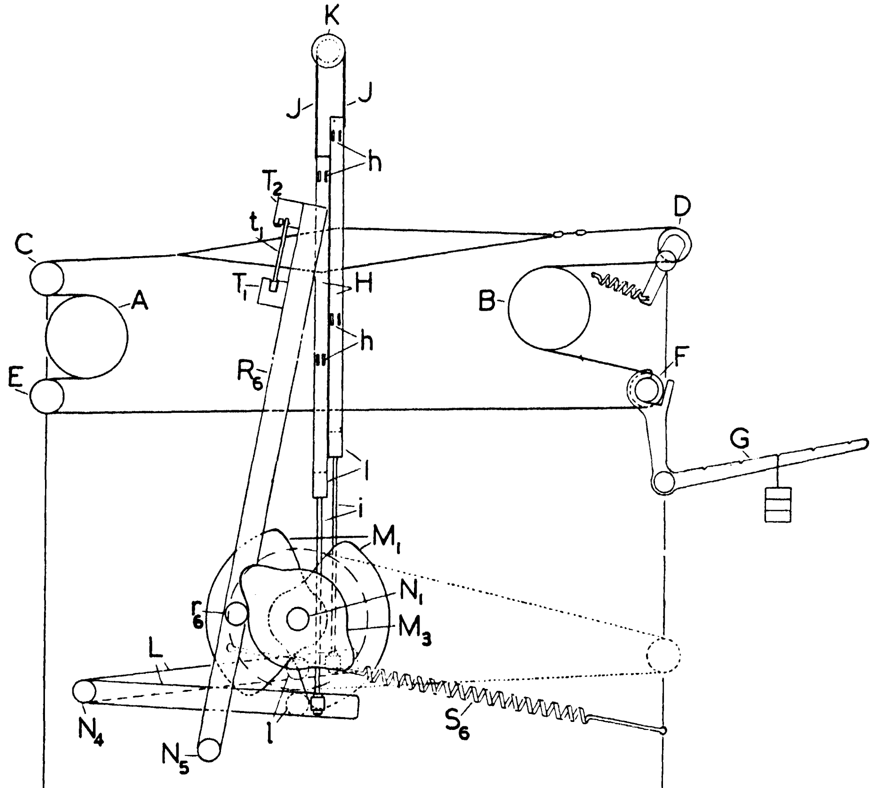


Fig. 2.

Position of Warp in Loom

The general lay-out of the warp in the loom can readily be seen by reference to Fig. 2, which is a diagrammatic sectional view of the machine with just the essentials illustrated. The depth of the loom, that is from breast-beam to back-shell, is approximately 38 inches, and the height from breast-beam to the floor approximately 31 inches. In Fig. 2, A is the take-up roller, B is what corresponds in this loom to the let-off roller, C is a roller acting as the breast-beam, D is a swinging back-shell, E is a guide-roller, and F is also a guide-roller used for tensioning purposes. These six rollers are positioned as shown in the figure ; the shafts of A and B revolve in enclosed bearings fixed to the loom framework and do not need to be disturbed. The shafts of C, D, and E revolve in half-bearings fixed to the loom framework, and that of F in half-bearings formed at the ends of the short arms of two similar bell-crank levers G fulcrumed about fixed points in the framework. The last-mentioned four rollers can therefore be readily

removed for gaiting the loom, and replaced on the inside of the yarn circuit. The purpose of the roller E is to help maintain the yarn or fabric in good contact with the take-up roller A, and also to position one end of the lower layer of yarn or fabric, so that the latter passes on to the roller F through the clear space between the bottom of the heddles and the top edges of the wooden cross-bars of the heddle frames below, there being no fouling of the yarn at the fully open position of either shed. (The position of the lower

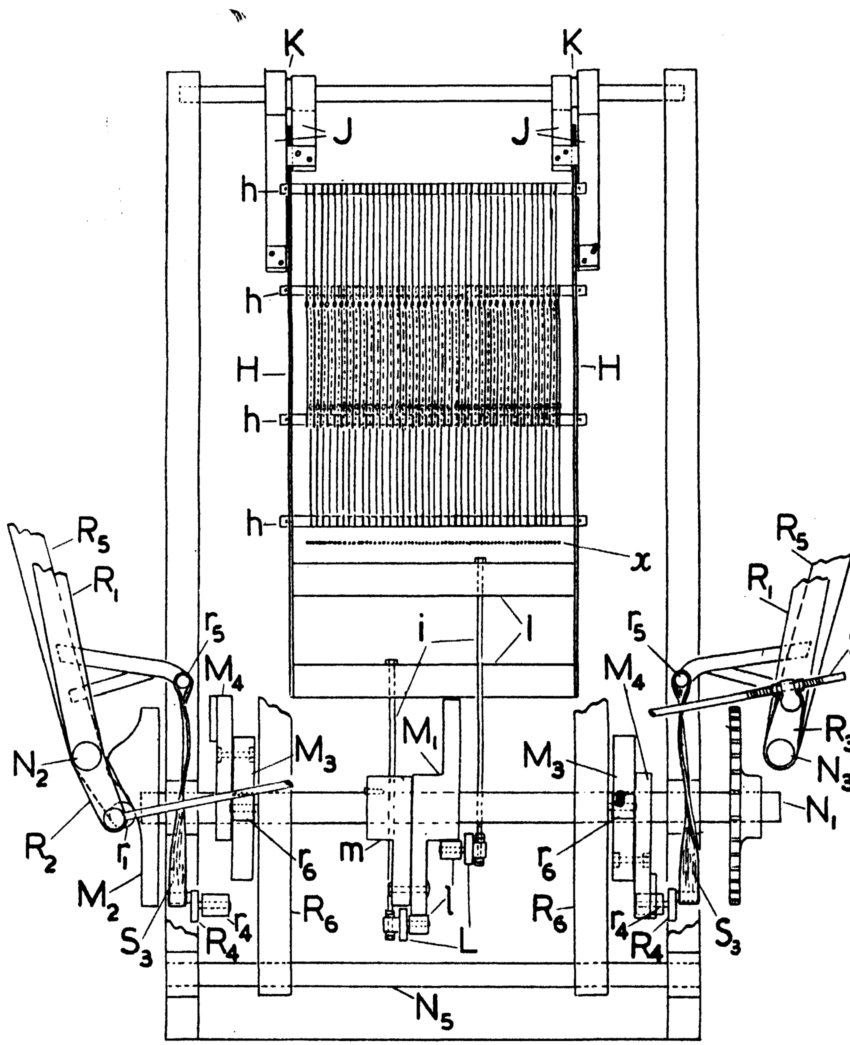


Fig. 3

layer of yarn with reference to the heddles is perhaps best seen in Fig. 3, at *x*.) In addition the roller F provides a ready means of tensioning the warp, and at the same time an accommodation for the continuous contraction in length as weaving proceeds, due to warp yarn corrugation. Suitable weights hung on the long arms of the bell-crank levers G supply a constant tension to the yarn through the roller F, and as the sample is woven the

shortening of the yarn/fabric circuit causes a slow rotation of the levers so as to carry F nearer to the centre of the loom.

The Heddles and Shedding

As was described in Part I of this paper, metal heddles are used in preparing the warp on the reel, and metal strips with a small hole at each end are threaded through the end loops at top and bottom of the heddles before doffing. The method of supporting in the loom the shafts thus formed is illustrated in front-view in Fig. 3 and in side-view in Fig. 2. Two frames with metal side-pieces H and wooden, lower cross-members I are slung by means of leather straps J one from each pair of rollers in an ordinary roller top-motion K. The ends of the eight metal heddle-supporting laths (for plain weaving), shown at *h* in the figures, are inserted into small slots in the sides H of the frames, and extend beyond these side-pieces just far enough to receive split pins into the holes at the ends ; this firmly secures the shafts for weaving. Fixed to each cross-member I is a vertical pull-rod *i*, connected, in a manner which allows of swivelling and also of adjustment to the length of the rod, to a treadle L which is fulcrumed, as already mentioned, at the front of the loom. The treadle-bowl *l*, supported on a pin in the side of the treadle, is moved in the usual way by its own member of a pair of tappets M_1 carried by the main shaft N_1. For convenience in setting the timing of the shed, the tappets M_1 are not secured to the main shaft but to a triangular-shaped piece *m* itself keyed to the shaft. A strong bolt between M_1 and *m*, through a radial slot in the latter, allows of quick and fine adjustment of the angular setting to the tappets.

Insertion of the Weft

Reference should now be made to Fig. 4, which is a perspective drawing of a portion of the left-hand side of the loom, showing in detail the mechanism for making and breaking the sley at each pick and for driving the shuttle through the shed. The sley O, a cross-section of which is also shown in Fig. 6, is of mild steel and is made in two similar halves. Each half consists of two flat strips O_1 and O_2 brazed together (the upper one O_1 being wider than the lower one O_2), and a third piece O_3 only about half the length of the other two, whose edge is fastened to the outer part of the base of O_2. The end of O_3 near to the middle of O_2 is shaped downwards in the form of a vertical lug with a slot, as shown in Fig. 4. The shuttle P which is of the ordinary type, has fixed to its base a curved iron strip *p*, which is shaped to the cross-section of O_1O_2 as shown, and allows the shuttle to be guided easily yet without too much play along the sley. A slight widening of the opening at each end of *p* and a slight taper on the inner ends of the two halves of the sley help to ensure the smooth transfer of the shuttle from one half of the sley to the other. The shuttle box Q is made of two pieces of angle-iron suitably held together by end straps in such a way that a slot is formed practically the whole length of the base, this slot being a little wider than the thickness of O_3. By this means the base of O_2 and the sides of O_3 are positively and smoothly guided by the bottom of the box Q. (This will be clear from Fig. 6.) Q is fixed with respect to the loom, being supported from the latter by stout iron straps, which are not shown in Fig. 4 but can be seen in the photograph in Fig. 1. The length of Q is such that the half-sley which it accommodates can be just totally " berthed," leaving the space between the two boxes completely clear of sley during the portion of the pick cycle when the reed is moving. During the remainder of the pick cycle, devoted to the insertion of

the weft, the sley-halves O are moved towards each other along the same line through the warp shed, and upon their reaching a position about an inch apart at the centre, the shuttle is picked from its box and slides from one half-sley to the other and on into the opposite box. After this the motion of the two sley-halves is reversed, and they are carried into their respective boxes again.

The mechanism which gives this reciprocating motion to each half-sley will now be described, with reference to Fig. 4. The vertical part O_3 of the sley is coupled through a stud in the slot in O_3 to a long lever R_1 which is fulcrumed, near the bottom of the loom, upon a side-shaft N_2. R_1 has a short arm below N_2 to which is attached an anti-friction roller r_1. This roller bears

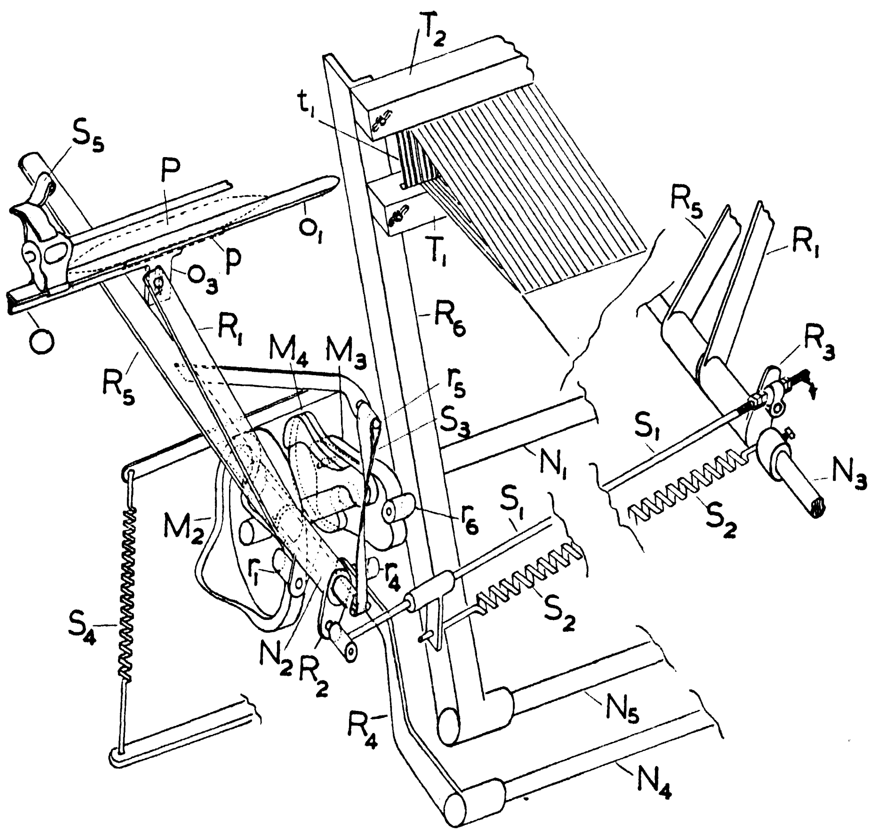


Fig. 4

against a face-cam M_2 fixed upon the end of the main-shaft N_1. Also attached to the same collar as R_1 is a short arm R_2 to which is pivoted a rod S_1 linking up R_2 with an arm R_3 fixed to the collar of the right-hand sley stick R_1 upon the side-shaft N_3. From the disposition of the various components, as shown in the figure, an outward thrust by the cam M_2 upon the roller r_1 results in an inward movement of both sley sticks R_1 and therefore sley-halves O, towards the centre of the loom. Following upon such a movement, the return of the sley into the boxes is brought about by the action of a strong spring S_2 connecting a bracket screwed upon the rod S_1, at the left-hand side near to R_2, to the right-hand side-shaft N_3. For the purpose of adjustment of the distance of the two sley-halves from each other when in

their fully-in or fully-back positions, the right-hand end of the rod S_1, where it joins R_3, is screwed and held in position by four nuts.

Whenever the sley is " made " according to the above description, the picking of the shuttle through the shed from one box to the other is accomplished in the following manner. Coupled to the beat-up cam M_3, which is keyed to the main-shaft N_1, is a picking-tappet M_4, in the path of which lies an anti-friction roller r_4 supported on a lever R_4 which is fulcrumed upon a shaft N_4 at the front of the loom. Directly behind the sley stick R_1 and fulcrumed on the same shaft N_2 is the picking stick R_5, and the inner end r_5 of a cross-arm attached to R_5 is connected to a point on the lever R_4 below by means of a leather strap S_3. The outer end of this same arm on R_5 is coupled by means of a coil spring S_4 to a portion of the loom framework below. At the top of the picking stick R_5 is a short, leather strap connection S_5 to a hide picker of the " overpick " type, guided on the usual rod along the top of the box, and also in this case by two small steel plates fastened to the sides of the picker and shaped outwards at the bottom to fit the top strip O_1 of the sley. The picking action is then quite straight forward, namely, the impact

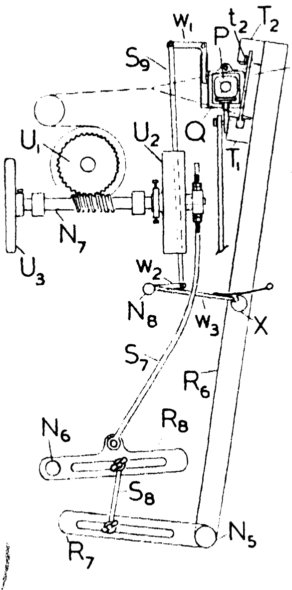


FIG. 5

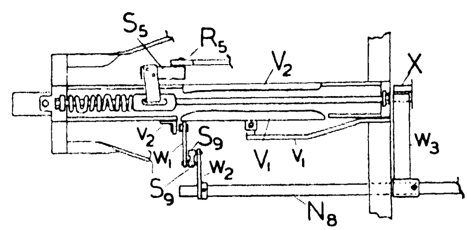


FIG. 7

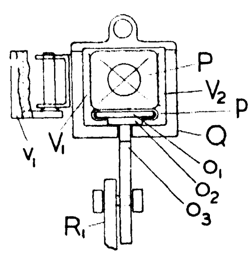


FIG. 6

of the tappet M_4 against the roller r_4, the depression of the lever R_4 and with it the downward pull of the strap S_3, thus causing the swing of the picking stick inwards. This is practically the normal underpick motion applied to a fixed box. The actual transmission of the stroke to the picker is accomplished by an action similar to that in the usual overpick motion. The picking tappet M_4 is bolted to the beat-up cam M_3 by a bolt in a radial slot in M_4, it being thus possible to adjust the timing of the pick within certain limits. In this connection, it should be stated that the shuttle is picked shortly after the sley-halves O begin to move towards each other and quite appreciably before they reach their innermost positions ; this allows the shuttle to reach and bridge the gap between the sley-halves without it

being necessary to give the latter a long pause at the centre, and so economises in time for picking.

There are one or two points which should be mentioned with regard to the elimination of the rebound of the sley stick and the picking stick. A strong duck-bill spring is fixed at the outside end of each box, so that upon the return stroke the outer end of the sley slides into the mouth of the duck-bill and is efficiently braked against possibility of rebounding. The effective strength of the spring for this purpose is controlled by a screw pressing on the top half. This braking mechanism is not drawn in Fig. 4, but can be seen in the photograph in Fig. 1. With reference to the return of the picking stick and picker, the tappet M_4 is designed to make this smooth, and also the usual leather buffer is inserted behind the picker on the end of its spindle.

Beating-Up the Weft

The open-topped reed or comb t_1 (see Fig. 4 and Fig. 5) has already been described in Part I of this paper. In this loom it performs only the functions of separating the warp threads and beating-up the weft yarn ; it does not serve as a guide for the shuttle in any way, and whilst picking is taking place it lies behind and just clear of the sley and the positively guided shuttle. In the loom the reed is placed in the hollow of a detachable wooden bar T_1, fastened by bolts and wing nuts across the two sword arms R_6, which are fulcrumed on the rocking shaft N_5. The upper bar T_2 is similarly attached to the swords, and its under side is grooved to take the top of the reed. An additional item is necessary, however, for the proper working of the latter. There being no definite side support for the reed wires, these tend during weaving to group together irregularly whenever the warp tensions are not perfectly uniform, and the side wires near the selvedges are especially distorted due to the reed-to-fell shrinkage. It is necessary, therefore, to insert between the reed wires at right angles to them and near the top of the reed, the pins of a special comb to act as spacers to keep the wires uniformly positioned under weaving conditions. The pins of this comb are quite short and are held in a brass stock of a length just equal to that of the reed, and the whole comb (shown in side-view at t_2 in Fig. 5) is accommodated in a recess in the bottom of T_2, and is held in position by two small brass catches, which can be swung below the base of the comb. Each sett of reed requires, of course, a particular spacing comb. It has recently been found of advantage to insert the spacing comb into the reed above the yarn before doffing the warp from the reel. A special small clamp has been made which fits round the comb so inserted, without distorting the pins, and securely holds the reed and comb together, This arrangement then forms a very compact and safe unit for transferring to the loom.

The method used for reciprocating the reed employs two cams M_3 on the main-shaft N_1 rotating against anti-friction rollers r_6 on the sides of the swords R_6. The rollers are kept always in contact with the cams by means of two strong coil springs S_6 (see Fig. 2) joining the swords to points at the back of the loom.

The Take-Up Motion

There is no winding-up of the cloth on a beam and the only function of the take-up roller A (Fig. 2) is to grip the surface of the fabric securely and pull it forward by the required amount at each pick. The former requirement is met by covering A with the usual sand-roller covering and arranging

the rollers C and E so that there is a large angle of contact between the cloth and roller A. The correct rotation of the take-up roller is accomplished by means of the following mechanism (illustrated in Fig. 5, which shows a side-view of the front of the loom). The shaft of the take-up roller is extended beyond the side of the loom, and to the extension is fixed a worm wheel U_1, which meshes with a worm on a cross-shaft N_7 below. To the back end of N_7 through a small friction-clutch of the type involving two hard wood pieces pressed against the shaft by screws in a semicircular collar, is coupled the outer shell of a friction ratchet U_2, the inner portion of which runs free on N_7 and carries near its rim a coupling for a connecting rod S_7 to levers below. These levers are R_7, fixed to the rocking shaft N_5, and R_8 fulcrumed on a stud N_6 which is held in a bracket on the side of the loom. Both R_7 and R_8 are slotted and are joined together by a link S_8 pivoted at both ends and to R_8 is also pivoted the lower end of the connecting rod S_7. The oscillation of the rocking-shaft N_5 is translated, through the above system of levers and connecting rods, into an up-and-down motion of the top of S_7, and, *via* the ratchet wheel and worm reduction gearing, into a small uniform, intermittent rotation of the take-up roller in a clockwise direction (in Fig. 5). The long slots in R_7 and R_8 allow for the setting of the link S_8 in a variety of positions to give a wide range of amounts of rotation of the take-up roller at each pick, that is, a wide range of shottings. A hand-wheel U_3 at the front end of the shaft N_7, enables the weaver to turn "back" the take-up roller, against the friction clutch on N_7 previously mentioned.

The Let-Off Motion

For a discussion of the letting-off of the warp, reference should be made again to Fig. 2. Considering the various rollers around which the yarn/cloth passes, the take-up roller A is the only one which is positively driven; B, C, E, and F can revolve freely in their bearings, and the surface of the swinging back-rest D is fairly smooth, so that the yarn slips over it without undue friction. If there were no frictional forces at all in the circuit (except round A), and also if the various rollers had no inertia, the tension in the yarn/cloth during weaving would be uniform throughout and equal to that imposed by the weights on the bell-crank levers G. In actual practice, the various rollers, especially B, show appreciable inertia effects and frictional forces come into play. The result is that when sudden increased forces are developed in the top line of the circuit between A and D, the latter responds comparatively quickly and helps to release the extra tension created whilst little of this sudden impulse is transmitted to the floating roller F. In other words, a considerable portion of the pick-cycle tension fluctuation is accommodated by the back-rest D, and the roller and lever system FG is free to adapt itself steadily, under the control of the dead weight, to the continuously diminishing length of the circuit.

It was found an advantage to cover the surface of the roller B with a thin layer of corrugated rubber to prevent any slippage of the yarn on the roller, and so obtain full value from the inertia of the latter.

Shuttle Checking and the Warp Protector Motion

In this loom, when the shuttle does not box, the swords and reed must be held in the fully back position. The mechanism used for warp protection is illustrated in Figs. 5 and 7, which include respectively a side-view and a plan-view of the shuttle box and stop mechanism. In Fig. 7, V_1 is a wooden

swell, pivoted near the middle of its outer plane face on a pin carried by one end of an arm v_1, which is fixed at the other end to the side of the box. At the back of the box is a second wooden strip V_2, which is almost parallel-sided. The inside face of V_1 is so shaped that, due also to the movement of the swell about its central hinge as the shuttle enters from the right, the effect is that the front of the shuttle presses outwards the left-hand section of V_1, and thereby causes the right-hand section of the latter to press home against the back of the shuttle. The final result is a continuous and steady retarding force along the whole length of the shuttle. Although the arm v_1 is very sturdy, there is a slight springiness in it, and the pin upon which V_1 is supported obtains during weaving a small movement, which is doubtless essential for the smooth checking of the shuttle. Bearing lightly against the outer face of V_1, near its left-hand end, is the curved tip of a small bell-crank lever w_1 which is pivoted on a bracket v_2 fixed to the side of the box. A connecting rod S_9 is taken down from the outer end of w_1 to an arm w_2 fixed to a rocking-shaft N_8, which is supported in bearings in the loom, and extends across to and beyond the other side of the latter, to carry mechanism exactly similar to that just described but associated with the other shuttle-box.

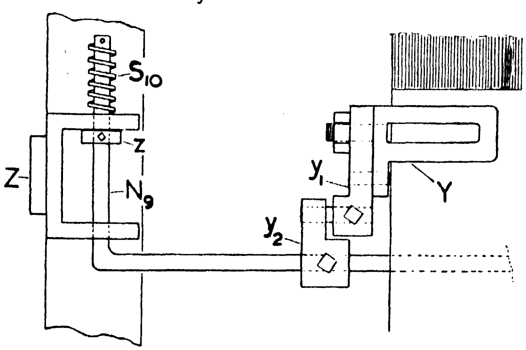


FIG. 8a

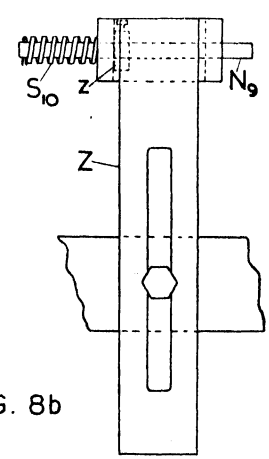


FIG. 8b

N_8 also carries near the inside of each loom gable a tongue w_3, which is in line with a stud X having a step or knee and attached to the side of the sword. When the shuttle boxes properly and V_1 presses the finger w_1 outwards, the effect is to raise w_3 clear of X, and the swords carrying the reed can come forward as usual for the beat-up. Otherwise, failing the entry of the shuttle to the full extent, w_3 engages the knee of X and prevents the sword leaving its backward position, the length of w_3 being such that there is only a small clearance between the end of it and X in the latter position. If such a stoppage occurs, the slipping clutch device in the drive comes into operation, and the loom handle is knocked-off by the weaver. Overthrow in an upward direction of the tongue w_3 during weaving is prevented by fastening a light leaf spring above it to the inside of the loom gable.

The Temples

Although the temples are quite standard, the method of mounting them on the loom is probably new and is illustrated in Figs. 8a and 8b, plan and side-view respectively. The temple Y is held by means of suitable

collars y_1 and y_2 for purposes of adjustment, on a rod N_9 which stretches across the loom below the top layer of cloth, and is bent through a right angle at each end to pass, at each side of the loom, through a bracket Z attached to the gable. The portion of N_9 which is held by Z carries a stop z on one side and a small coil spring, washer and split pin S_{10} on the other side of the back leg of the bracket. This arrangement ensures the usual freedom of the temples in the direction towards the breast beam. As will be seen from Fig. 8b, the vertical leg of the bracket Z is slotted, which allows for ready adjustment of the height of the rod N_9. When a new warp is being put into the loom, this rod with the temples must be removed, and re-inserted on the inside of the yarn circuit

The Timing of the Operations

As will be clear from the above account, all the operations involved during the weaving derive their motion from cams on a single main shaft, which revolves once completely for every two picks. These cams have to be designed in the first place to suit the particular motions involved, and in this consideration the timing of the operations in the required sequence has an

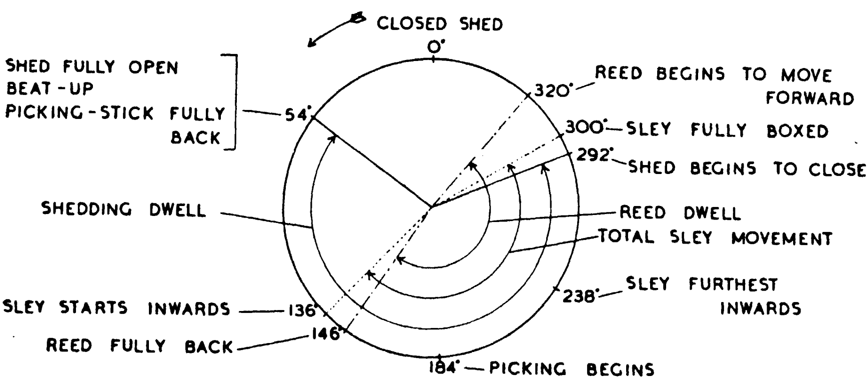


Fig. 9.

important bearing upon the shapes of the cams. The timing circle for the loom, as in use at present, has been drawn in Fig. 9. This is upon the basis of 360° for one pick cycle, in order to bring it into line, for the sake of familiarity, with the usual loom timing circle based upon the revolution of the crank-shaft. Calling the closed shed position zero degrees, the dwell of the shed is from 54° to 292°, or 238°; the dwell of the reed in the fully back position is from 146° to 320°, or 174°; and the angle devoted to the complete movement of the sley is from 136° to 300°, or 164°. The shuttle is allowed from 184° to 238°, that is 54°, to travel from its position of rest in the box to one half-way across the shed, and upon the assumption that this allowance is just correct, the shuttle will be properly boxed at the opposite side of the loom at 238° + 54°, that is 292°, leaving from 292° to 320°, or 28° for the warp protector mechanism to operate.

The cams which give the timing circle shown in Fig. 9 are those which were originally designed for the loom when the whole mechanism had reached no further than the drawing board stage, and, realising the importance of the interdependence of the timings of the various operations fairly liberal allowances were made in the matter of dwells of the cams. During

construction of the loom, these cams were made to be readily adjustable in angular displacement with regard to each other on the main shaft, and the positions were soon found which gave satisfactory working. There is little doubt that if experimental work were continued, useful alterations could be made in the lengths of dwell and the timing of the various parts within limits. For the purpose of the present work, however, it is of no advantage to follow up this point.

The speed at which such a loom as the above can be run is obviously finally determined by the rate at which the sley-halves are moved in and out of the shed (assuming that the time occupied by a half-sley in returning from the centre to the side of the loom is always greater than the time taken by the shuttle over the same distance). In view of the type of construction of the sley, and the conditions which must be observed for smooth working, such as good alignment of the two halves on meeting at the centre of the loom and freedom from excessive hammering on the return of the sley to the boxes, it is not practicable to speed up the motion of the sley parts excessively. In the early stages of the trials before many minor improvements which would help to make higher speeds possible had been made to the sley mechanism, it was found that a loom speed of between eighty and ninety picks per minute was a comfortable working rate, and this speed has been adhered to. This is slow by ordinary standards, but in the case of sample making under discussion here, high speed of weaving is not really important ; the weaving of a full sample, wefted with sixty picks per inch, would take about an hour, whereas the reeling time for the warp for such a sample, with say fifty ends per inch, would be about three hours.

Modifications to Ordinary Loom for Weaving Sample Warp

The additional equipment and the alterations to an ordinary loom, for the purpose of weaving a sample prepared on the new reel, are so small that this method of dealing with the sample warp is very convenient for factory use. One of the chief requirements is a special small beam upon which the warp is wound. Fig. 10a shows a side-view of this beam A supported in a stand B, which is placed near the reel, on the opposite side to the magazine, when it is desired to doff the warp and wind it on to A ready for weaving. Fig. 10b shows a plan-view of the beam and its stand. The beam is made of wood, and is 7 in. in diameter and 15 in. long. It is supported on a $1\frac{1}{2}$ in. shaft C of a length to suit the distance between the loom gables ; the beam is bored to a greater diameter than that of the shaft, and has fixed to it at one end a plate carrying a $1\frac{1}{2}$ in. bush and at the other end a pace-pulley also bored to $1\frac{1}{2}$ in. (shown at D and E in Fig. 10b). A set-screw in E can be used to fix the beam to the shaft during winding-on the warp ; during weaving this screw is loosened, and A can revolve on C between two collars screwed to the latter. The beam contains a slot F parallel to its axis and of such dimensions that one of the yarn clamps is just a tight fit in it, the edge of the clamp from which the yarn appears being to the outside of the slot and just below the surface of the beam. A small recess is made in the middle of one side of F to take the wing-nut on the clamp. This arrangement allows of the warp being lapped several times round the beam smoothly and without any interference from the clamp. The shaft C rests in bearings in uprights G of the stand B, and to these uprights are fixed four iron strips H situated and shaped as shown in the figures. The straight portions of H further

from the beam have a series of notches in the upper edges, and are also of such distances apart that a leaf or shaft of heddles J can be taken from the the reel and suspended in the framework formed by the four pieces H, the ends of the two laths through the top and bottom loops of the heddles falling into four corresponding notches in H. All the heddle shafts it is possible to form on the reel can be accommodated side by side in this way on the stand B. The procedure then in taking the warp from the reel is as follows. Two yarn clamps are placed across the warp on the side of the reed further from the first heddle shaft and tightened-up in position near to each other, after which the yarn is cut between the two. The clamp further from the reed is then placed in the slot F in the beam A, and the latter is rotated

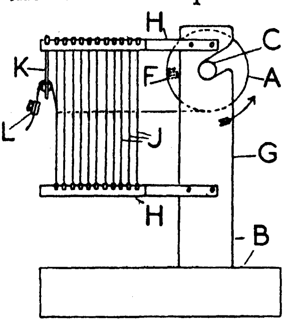
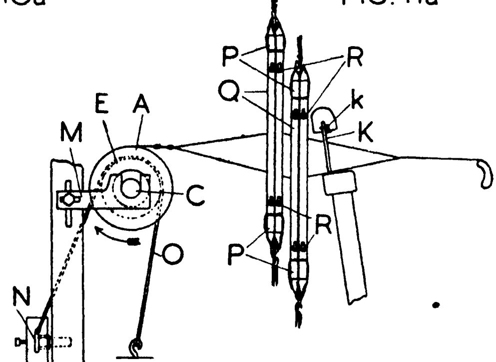


FIG. 10a

FIG. 11a



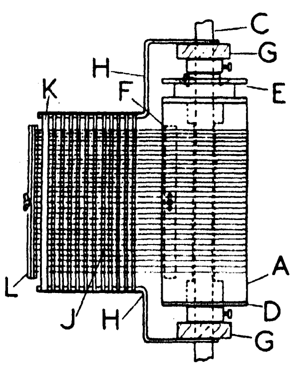
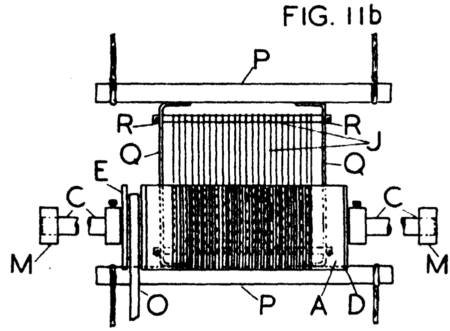


FIG. 10b

FIG. 11b



so as to wind-on the yarn from below (both beam and reel rotate anti-clockwise from the point of view of the operator). As each shaft of heddles comes round to the bottom of the reel, it is released from the latter, moved along the yarn, and placed in its notches on the framework H. When the last heddle shaft J has been disposed of in this way, the reed K follows and is similarly supported (upside down), there being then only a short length of yarn left held by the clamp L. It is then a simple matter to gather together beam, heddles, reed and clamp, and carry them to the loom for weaving.

The position of the beam in the loom is illustrated in Fig. 11a, which is a sectional side-view of the middle portion of an ordinary loom upon which are mounted the usual under-tappets for plain shedding and also a dobby above for dobby shedding. The beam shaft C is supported in bearings in

brackets M adjustably bolted to the loom gables in such a position that the top of the beam A, where the yarn is leaving, is situated just behind the place normally occupied by lease-rods in the ordinary arrangement. This allows as much of the yarn on the beam as possible to be woven. Letting-off of the beam is controlled by the existing drag-weight and lever N, from which a lengthened chain O passes round the pace-pulley E on the end of A. The method of mounting the heddle shafts J is illustrated in Fig. 11b which is a back-view of this part of the loom. To the ordinary wooden heddle laths P, which are attached by cords to the shedding mechanism, are fixed vertical iron strips Q of a length and width apart just suitable for accommodating the heddle shafts as shown. The ends of J are slipped through narrow slots cut into the top and bottom of Q and extend beyond the sides of Q just sufficiently for spring-clips R to be inserted into small holes in the ends of J. The wooden shafts P and the iron joining strips Q form a framework which is left permanently in the loom. The reed K and its spacing comb *k* are held in the loom in a manner exactly similar to that in the case of the sample loom, except that here the reed being narrow compared with the reed-space it is necessary to insert a thin, smooth plate on each side of the reed, between it and the shuttle-box, for the purpose of guiding the shuttle.

Apart from these slight modifications, all else is normal with respect to the loom. The yarn clamp in front of the reed is removed and the ends pulled straight and knotted into the carry-cloth in the usual way ; the height of the beam is adjusted so that the line of the warp through the loom is suitable for obtaining good cover, etc.; and the weighting is naturally smaller than is usually employed on a large number of ends. The beam can be woven round until the slot in it is just behind top-centre on the last lap, that is there is only an inch or two of warp remaining on it. Including the forward end of yarn knotted into the carry-cloth at the beginning of the weaving, there is, therefore, a total loss of less than three feet of yarn, and approximately seven feet of sample cloth are woven.

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

16—THE INFLUENCE OF HYDROGEN ION CONCENTRATION ON ADHESIONAL WETTING BY SOAP SOLUTIONS.

By J. Powney and H. F. Frost.
(British Launderers' Research Association).

One of the functions of a detergent is to penetrate a soiled fabric and wet the soiling material. If spreading can also occur, the detergent will be more efficient in " wetting out " a fabric than a detergent which merely wets the material. Whilst, however, there is a large number of methods available for determining the rate of penetration of liquids into fabrics and powders, there is no very satisfactory method for evaluating adhesional wetting. The methods of Bartell and his co-workers[1] on the wetting of powders unfortunately do not lend themselves to the study of textile fibres which can absorb water, nor to the investigation of highly surface-active substances of which the concentration can vary appreciably by adsorption during penetration.

The criterion of wettability adopted in this paper is the angle of contact made by the detergent with the solid phase, measured in the detergent in all cases. In view of the considerable variation of nomenclature to be found in the literature, the terms used are defined below.

Wetting. If the profile of a liquid forms an angle of less than 90°, measured in the drop, with the phase with which it is in contact, the liquid is said to wet that phase.

Adhesional Wetting is the term applied to the wetting of surfaces under the influence of attraction between molecules of the phases concerned.

Capillary Wetting occurs when a liquid penetrates a regular or irregular capillary system.

" *Wetting Out* " is a technical term applied to the entrance of liquid into a fabric. When completely " wetted out " there will be no air in the capillary spaces present. In the case of fibres permeable to the liquid concerned, the intra-fibrillar capillaries will be filled in addition to the inter-fibrillar spaces.

Spreading. A liquid which forms an immeasurably small contact angle, θ, when in contact with another phase, is said to spread over that phase.

EXPERIMENTAL.

The most convenient method for the measurements of contact angles on textile fibres was found to be a modification of the " bubble-machine " of Taggart, Taylor and Ince[2] (Fig. 1). Bubble holder and pipette were ignited between measurements. In the case of fibres the free end of the platinum wire was bent to form a bow across which the fibre was fixed by small drops of de Khotinsky cement. It was found possible to attach the fibres rapidly and without handling in any way the centre portion used for measurements.

When investigating the contact angle on paraffin wax the free end of the platinum wire was bent at right angles, ignited, and brought into contact with the wax. A smooth coating was easily obtainable by choosing the right moment for melting the wax, and passing the wire through the molten wax at the appropriate rate. In most cases zero contact angle was checked by using Rehbinder's method, a bubble being blown beneath a flat paraffin-coated surface. This procedure was adopted after it had been found that extremely vigorous tapping would occasionally cause a bubble which had been resting against the paraffin with zero contact angle, to adhere suddenly with an angle of sometimes 50°, which value was maintained as the bubble was moved along the wire by means of the holder. This effect was most pronounced at the higher soap concentrations and higher pH values[3].

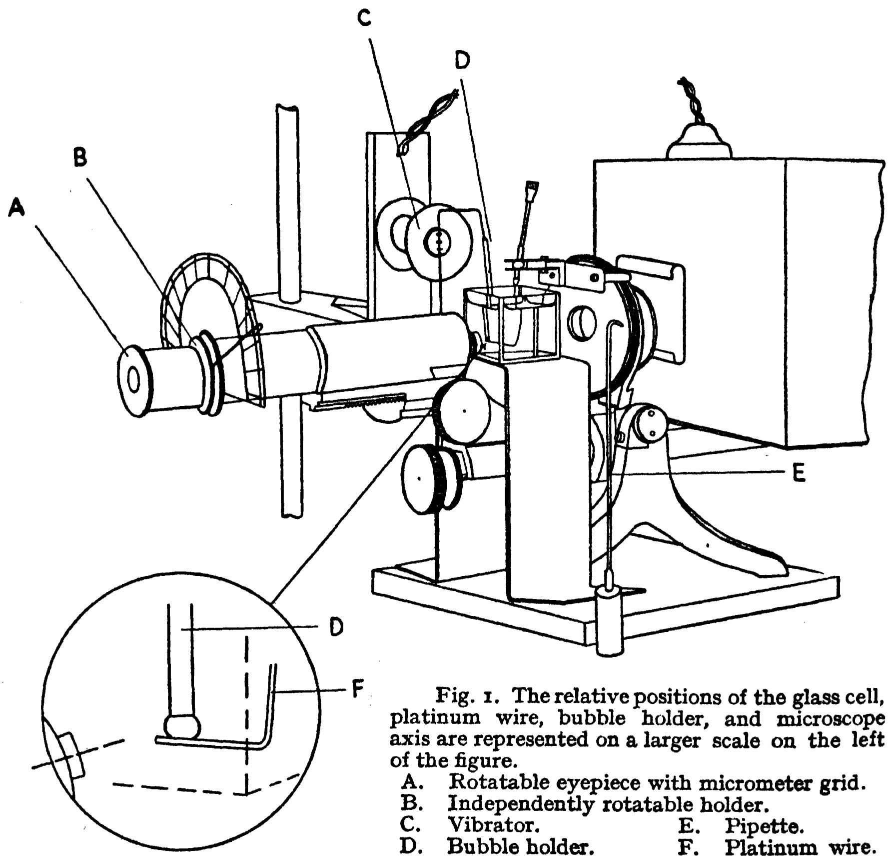


Fig. 1. The relative positions of the glass cell, platinum wire, bubble holder, and microscope axis are represented on a larger scale on the left of the figure.

A. Rotatable eyepiece with micrometer grid.
B. Independently rotatable holder.
C. Vibrator.
D. Bubble holder.
E. Pipette.
F. Platinum wire.

Advancing and receding angles were measured by very slowly rotating the stage bearing the wire-holder, until the bubble just receded or advanced respectively. Equilibrium angles were measured after the vibrator had been switched on. This was connected in series with the lamp used, and had a frequency of approximately 100 vibrations per second. In most cases there were two profiles of the bubbles, one faint, the other distinct. The former, which was due to an occasional recession of the liquid to the "receding angle," was neglected, the distinct equilibrium position being measured. The mean of ten observations was taken in most cases. All measurments were

made at room temperature which, throughout the period of the experiments, was $23° \pm 2°C$.

In most instances, using water or buffered or unbuffered soap solutions and paraffin wax, the maximum variation in the equilibrium value of the contact angle in the range $15° - 100°$ was $2°$. Below $15°$ the angle could only be estimated within $5°$, but generally the bubble did not adhere at all below $15°$. It should be noted however that it is the cosine of the contact angle which enters into the expression for the equilibrium of the bubble and that the cosine exhibits smallest variation with θ, when θ is small. There was a greater variation in the advancing and receding angles, usually of five degrees, although in certain cases when separation of fatty acid occurred, a difference of ten degrees was observed.

The above values refer to two series of five observations on different regions of the surface of the solid, both solution and solid being renewed for the second series. The values obtained were reproducible on subsequent occasions, within the limits of the experimental error except in unbuffered soap solutions. In the latter, reproducibility could be obtained by diluting from the same freshly prepared stock solution, using the diluted solutions as soon as possible, and taking the same time for measurement so that equal exposure to air occurred.

Sodium oleate and sodium laurate were prepared according to the method previously described[4]. From a freshly prepared 0·5 per cent. stock solution the required dilution was made, the flask and contents heated on a water bath at 80°C. for five minutes, and then cooled to room temperature. The liquid paraffin used was "Nujol," and the paraffin wax had a melting point of 57°C. The contact angle made by water against the wax and air using Rehbinder's bubble method[5] was identical with the value given by that author (106°), and was unaffected by the addition of caustic soda to the water. All water used was redistilled from alkaline permanganate in the absence of CO_2. Buffer solutions were prepared from pure recrystallised sodium phosphates and checked against buffers calibrated by means of the hydrogen electrode. The *p*H measurements were made in the Morton glass electrode system, a correction for the sodium ion effect being applied where necessary. Sodium chloride was of the "Analar" grade.

RESULTS.

(1) *Qualitative.* In the case of two liquids, it is a necesssary, but not sufficient, condition for spreading that wetting should occur. Moore and Graham[6] stated that the ability of kerosene to spread on water and the inability of water to spread on kerosene can be demonstrated even when the lower liquid is supported on filter paper.

When this experiment was repeated, by soaking a filter paper in kerosene and placing a water drop on it, the drop penetrated into the paper, displacing the kerosene. A similar result was obtained when "Nujol," which does not spread on water, was used. An unpolished ebonite slab was then substituted for the filter paper. Kerosene spread readily on this surface, and water, although not spreading spontaneously, could be formed into a stable film by means of a glass rod. The effect described by Moore and Graham was then obtained, for the kerosene spread over the film of water, but a water drop placed on the kerosene treated surface came to equilibrium when the edge of the drop made an angle of about 60° with the horizontal. Experiments were therefore made to test which of the two factors, capillary spaces or hydrophilic

molecules, was responsible for the failure to obtain these results in the case of filter paper. A sheet of cellophane was treated with kerosene and a water drop placed on it. The cellophane beneath the drop commenced to cockle almost immediately and the drop then flattened out, although the increase in the area of water in contact with cellophane was very slight compared with that obtained using filter paper. It would appear therefore that whilst capillary spaces in the solid assist wetting out they are not primary responsible for the displacement of the kerosene by water. This was confirmed by

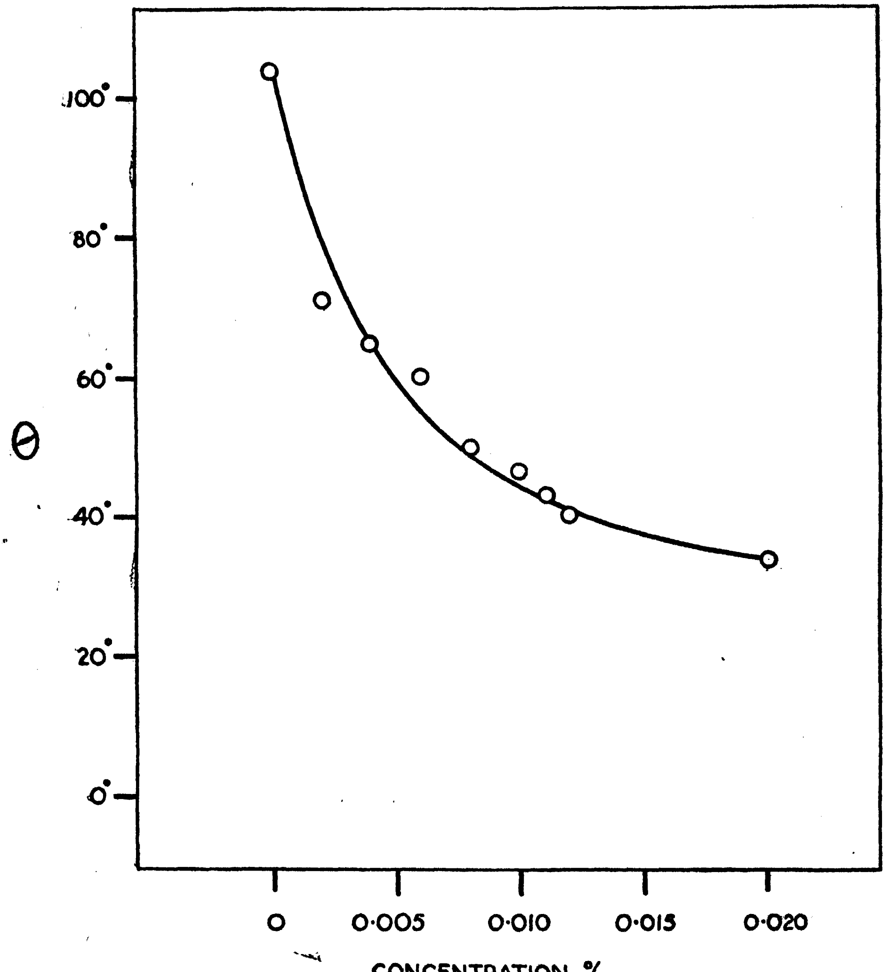


Fig. 2. Paraffin wax/air/sodium oleate.

treating a filter paper with a dilute solution of a waterproof varnish, and drying. When the treated filter paper was soaked in kerosene and a water drop placed on it, the drop remained spherical, showing no tendency to penetrate. That the capillary spaces had not been destroyed was confirmed by adding a very small amount of sodium oleate solution to the water drop, when instant penetration and displacement of the oil occurred.

(2) *Quantitative.* A number of measurements was made on the system solid/air/water, where the solid was either in the form of a fibre or was coated on to a 0·3 m.m. diameter platinum wire.

Paraffin wax gave an equilibrium value of 102°, 4° lower than that obtained using Rehbinder's method of coating on a plate which was used to support the bubble. The platinum wire alone gave very variable angles depending on time of ignition and cooling, smoothness of wire and other factors, whilst glass under the same conditions gave zero contact angle. Since Nietz and Lambert[7] have shown that the pull on the ring in the du Nouy method of measuring surface tension is affected by contact angle, the use of a platinum wire may in certain circumstances give rise to small errors.

The mean advancing angle for three types of scoured wool fibres taken from samples of felt in the air dry state was 55°, the mean receding angle being 25°. The advancing and receding angles for acetate rayon were 30° and 12°, for cuprammonium rayon 17° and 7°. Fibres from an unbleached cotton fabric, boiled in water and dried, had advancing and receding angles of 30° and 17°. In this example, and for tussah silk also, the angle was dependent upon the position of the ribbon, being greater when it was flat than when vertical.

A difference between the advancing and receding angles ("kinetic hysteresis") attributed by Adam[8] to molecular friction was observed in all cases. The non-uniformity of the surface however did not justify the use of the cosine mean for the calculation of the equilibrium angle, although in general the observed equilibrium value approached closely the mean of the advancing and receding angles. Particularly with wool, the "edge effect"[9] or "dispersion hysteresis"[10] must have a considerable effect in deciding the *measured* contact angle.

(a) *Dependence of θ on soap concentration.* The effect of variation in the concentration of pure sodium oleate on the contact angle in the system paraffin wax/air/soap solution has been investigated and the results are shown in Fig. 2. Even at low concentrations there is an appreciable decrease in θ. The concentration at which adhesion of the air bubble just failed to occur was rather uncertain owing to the effect previously mentioned, although 0·05 per cent. seems to be the maximum concentration at which adhesion can occur. The phenomenon is probably comparable with that studied by P. Rehbinder and E. Wenstrom[11], where the stability of a drop at an interface was taken as a measure of the degree of saturation of the adsorbed film. Rehbinder's[12] value of 0.004 per cent. for C_1, the concentration at which the contact angle is 90°, was not confirmed, and it seems probable that Rehbinder's sample of sodium oleate contained a small proportion of free alkali which would have a very great effect on the magnitude of the contact angle θ.

(b) *Dependence of θ on p*H. The effect on *p*H on contact angle was first investigated by the addition of 0·1 *N* NaOH to various concentrations of sodium oleate. The first addition produced a rapid increase, but after 1 cc. had been added to 100 cc. of detergent, subsequent addition had comparatively slight effect. The presence of irregularities in the initial portion of the curve was further investigated by decreasing to 0.02 cc. the increments of 0.1 *N* NaOH added to 70 cc. of detergent. After 0.7 cc. had been added, a fresh solution containing 1 cc. 0·1 *N* NaOH per 100 cc. of detergent was prepared and another 0.7 cc. added in 0.02 cc. increments. This procedure was followed for the remaining parts of the curve (Fig. 3) which as can be seen run together quite satisfactorily. There are three peaks in the curve, which were obtained in similar positions when a 0·1 molar solution of

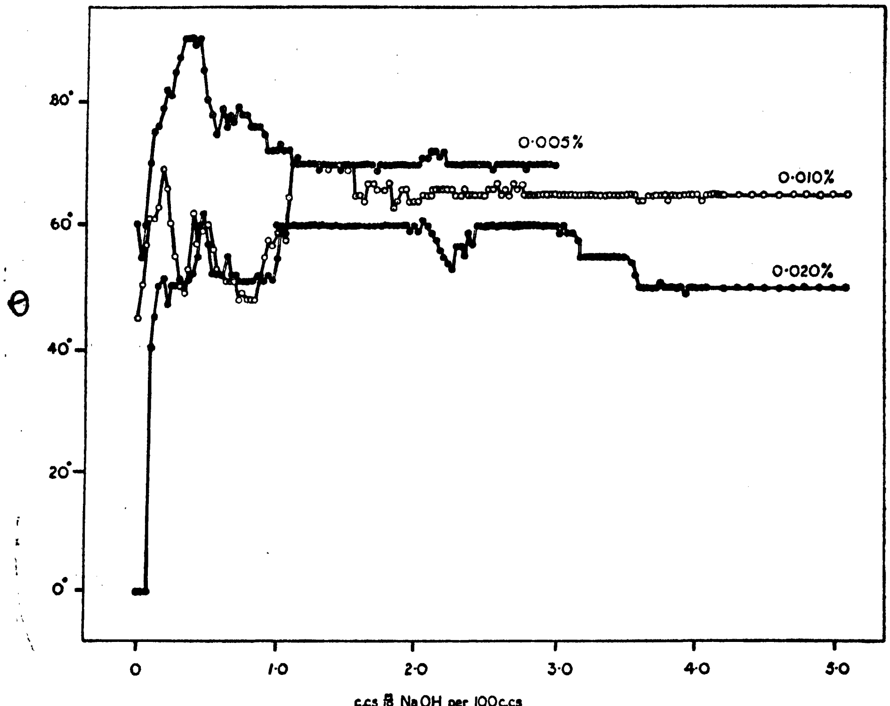


Fig. 3. Addition of $\frac{M}{10}$ sodium hydroxide to paraffin wax/air/sodium oleate.

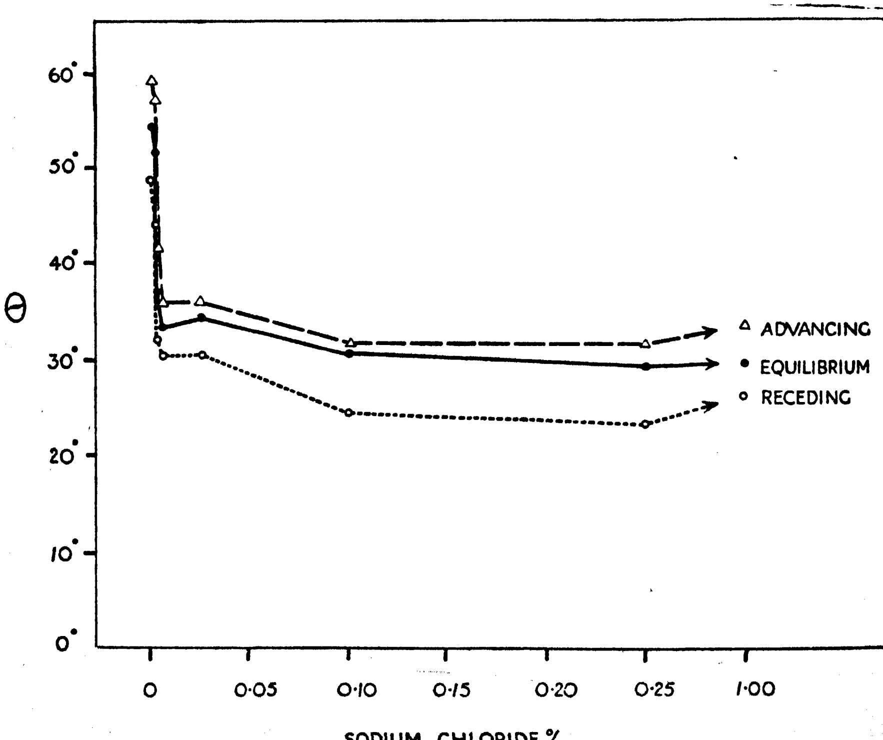


Fig. 4. Paraffin wax/air/0·01% sodium oleate + sodium chloride.

trisodium phosphate was substituted for the NaOH. This effect may be compared with the stepwise change of the surface tension of a 0·1 per cent. sodium oleate solution which occurs upon addition of alkali[4]. It is of interest to note however that although the *p*H of the solutions at which the peaks occur correspond approximately, the *p*H- alkali concentration curve for the same soap solution is smooth and not stepped over this range.

In view of the close connection between surface tension and θ, and the effect of CO_2 in lowering surface tension by reducing the *p*H, it was thought advisable to buffer the solutions with 0·25 per cent. phosphate buffer when

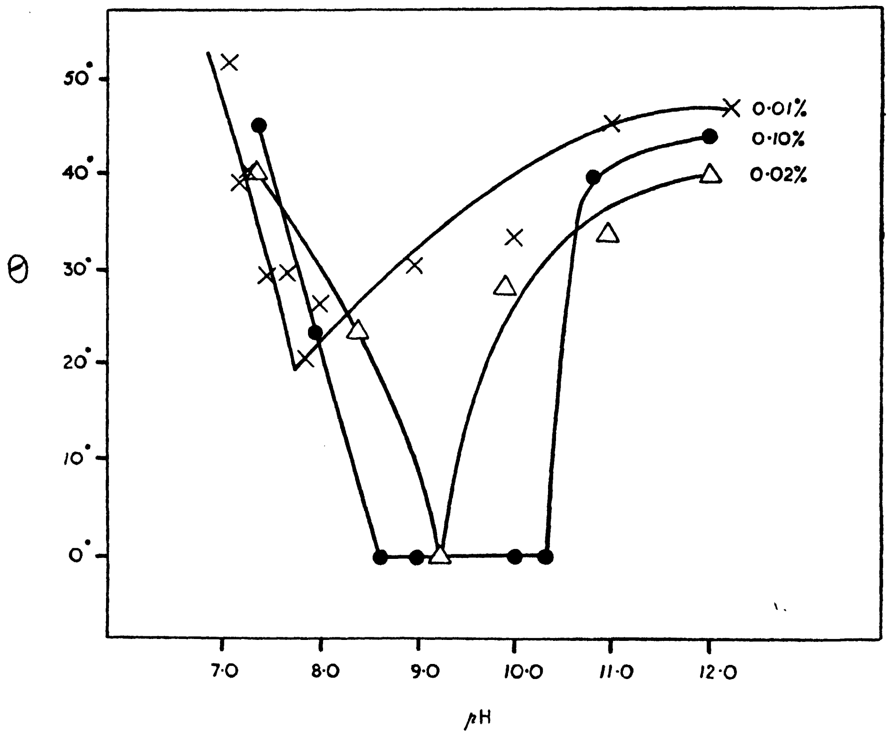


Fig. 5. Paraffin wax/air/sodium oleate.

studying the effect of *p*H on the contact angle. Sodium chloride at this concentration was found to produce a considerable decrease in the contact angle in comparison with a plain soap solution, and the effect was therefore studied in greater detail using a 0·01 per cent. solution of sodium oleate containing varying amounts of sodium chloride. As can be seen from Fig. 4, very small concentrations have a marked effect, but in the region of 0·25 per cent. a considerable variation in the amount present can be made without appreciably altering θ. It was found that the addition of sodium chloride was practically without effect on the *p*H of the solution in the range over which maximum variation in θ occurred. This effect of low sodium chloride concentration may be compared with the increase in emulsifying power obtained by L. Kremnev and T. Papkova-Kwitzel[13].

The variation of θ with *p*H was studied in the system paraffin wax/air/sodium oleate, using 0·25 per cent. phosphate buffers. The experimental results are represented in Fig. 5, where the equilibrium angles only are shown.

In the case of 0·01 per cent. sodium oleate there is a minimum contact angle in the region of *p*H 8·0. Solutions were slightly cloudy under these conditions, but there was no deposition as was found for the sodium laurate solutions at low *p*H values. The change of contact angle with *p*H diminished rapidly above *p*H 11·0.

When a 0.02 per cent. solution of sodium oleate was used the contact angle was reduced to the spreading point in the neighbourhood of *p*H 9·0.

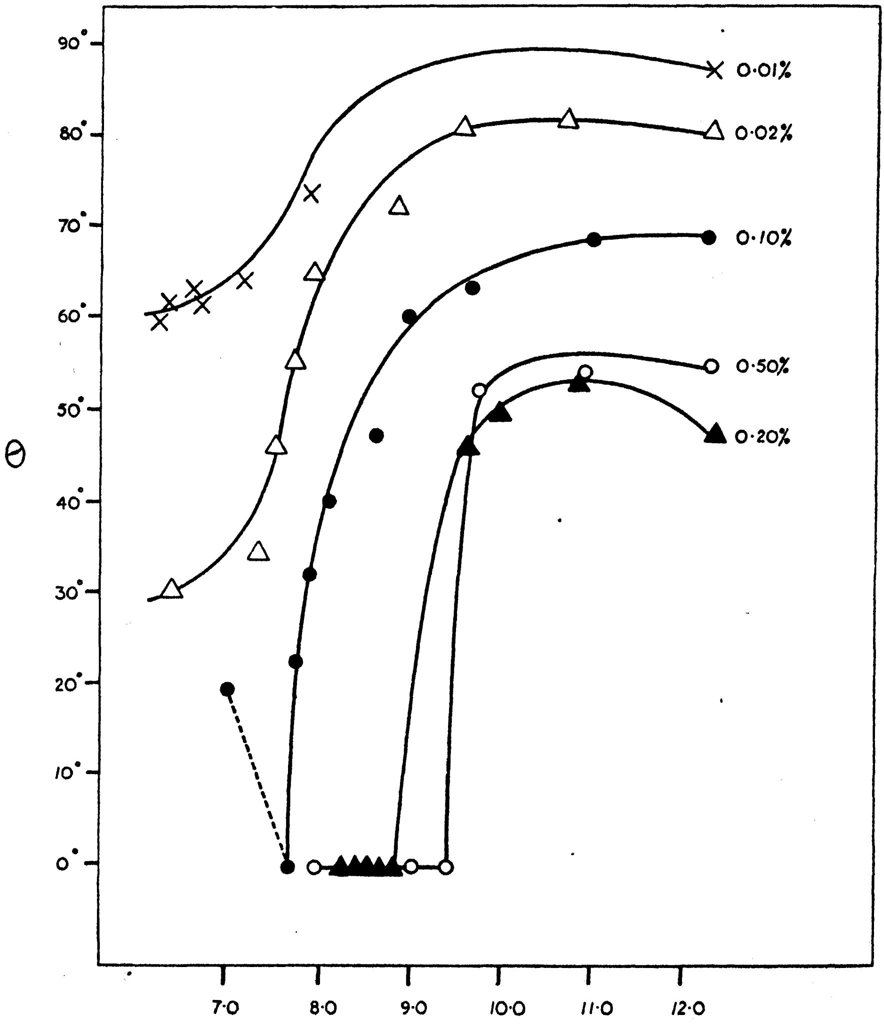


Fig. 6. Paraffin wax/air/sodium laurate.

The " kinetic hysteresis " increased as the turbidity of the solution was increased by reduction of *p*H. Further increase in soap concentration to 0·1 per cent. broadened the *p*H range in which spreading could occur, although just outside this range the contact angle was very sensitive to *p*H change. Again θ increases only slightly with increasing *p*H above *p*H 11·0.

Fig. 6 represents the results obtained using paraffin wax/air/buffered sodium laurate. It can be seen that especially at low concentrations wetting

is much inferior to that obtained with the same weight concentration of sodium oleate. The equilibrium value of the contact angle continued to decrease past the point of incipient turbidity, until separation of solid particles of fatty acid occurred. Measurements could not be extended beyond this, owing to the aggregation of the particles at the boundary of the bubble. There is a tendency for θ to decrease above *p*H 11·0. In the case of 0·1 per cent.

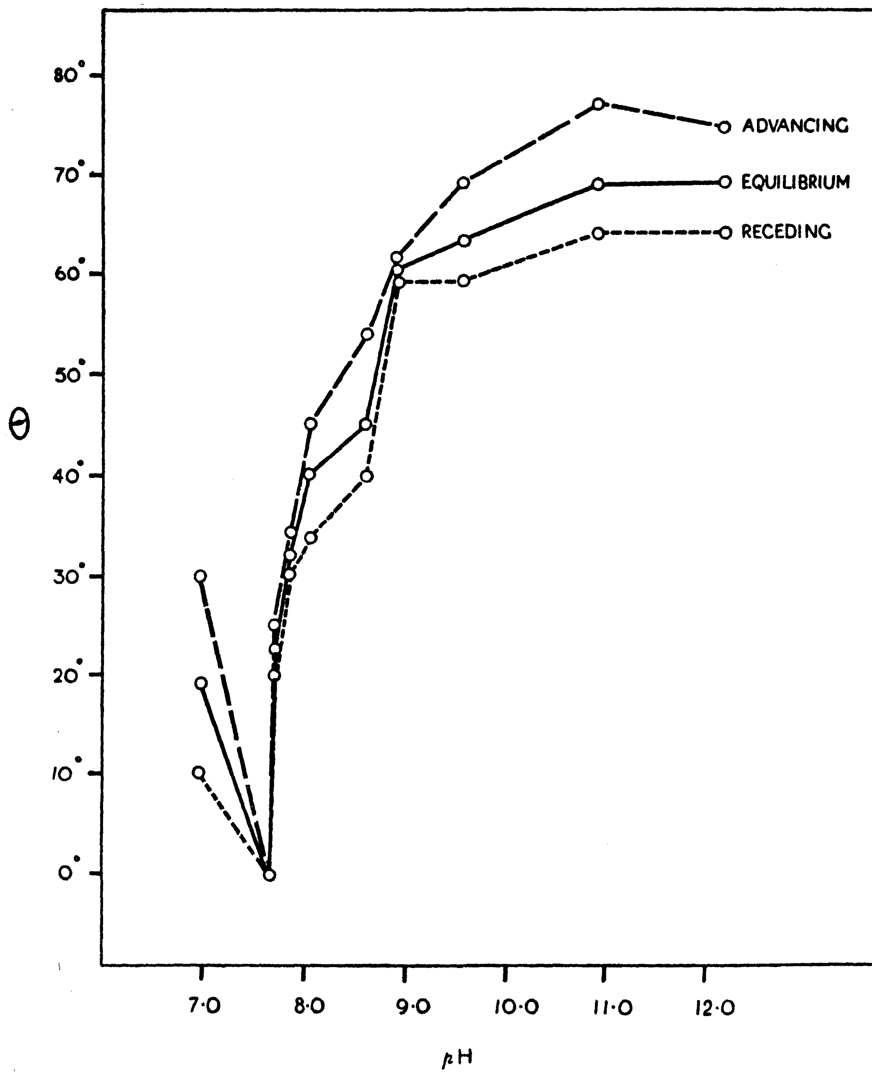


Fig. 7. Paraffin wax/air/0·1% sodium oleate.

sodium laurate spreading occurs only in a narrow range on the border of the turbidity region. With higher concentrations of laurate, however, spreading can still be obtained when the alkalinity has been increased until the solution is no longer turbid. A 0·2 per cent. solution of sodium oleate even at *p*H 12·25 gave zero contact angle in the same system paraffin wax / air / detergent.

Fig. 7 for 0·1 per cent. sodium laurate is typical of the observations made at each soap concentration. Whilst the hysteresis varies with *p*H, being

greatest at *p*H 7·0 where fatty acid separates, in each instance the observed equilibrium value of the contact angle lies almost midway between the advancing and receding angles.

Fig. 8 represents the results obtained in the system wool/air/buffered 0·1 per cent. sodium laurate. Compared with Fig. 7 it can be seen that spreading is occurring at a *p*H where a contact angle of 45° is obtained against paraffin wax. This is in qualitative agreement with the relative values obtained for the contact angles of the wool and wax against water. When the sodium laurate concentration was increased to 0·2 per cent., spreading occurred over a *p*H range 7·5 – 9·6, and even at *p*H 10·95, values for the

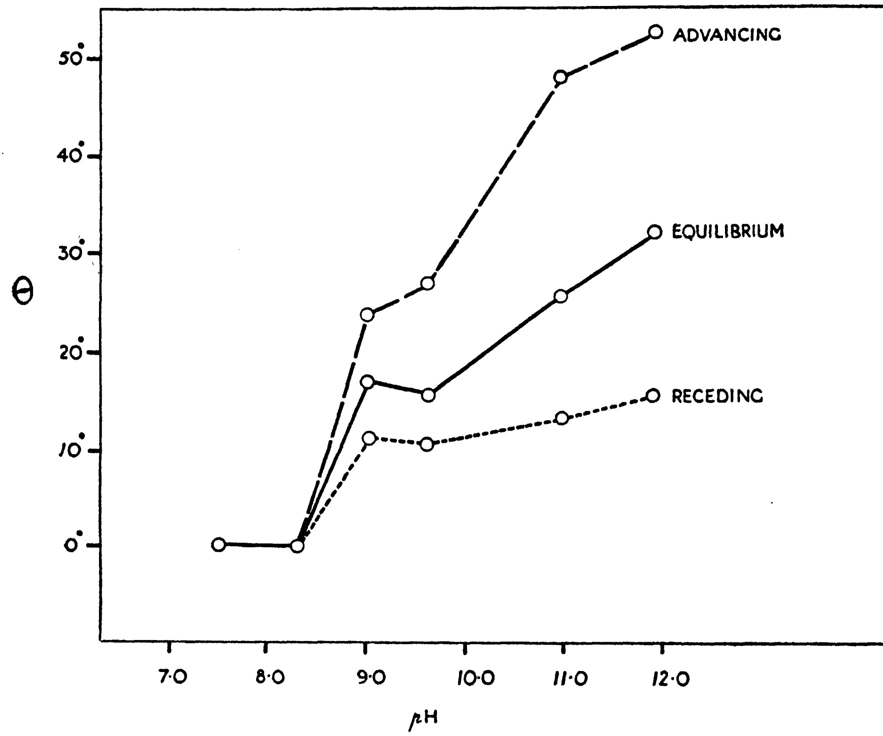


Fig. 8. Wool/air/0·10% sodium laurate.

equilibrium advancing and receding angles of only 15, 20 and 10 degrees respectively were observed. Sodium oleate, both at 0·2 per cent. and 0·1 per cent. gave zero contact angle over the *p*H range 9·7 – 12·25. Measurements at low concentrations are probably rather unreliable owing to the formation of acid soap at the surface of the wool.

Fig. 9 represents the change of contact angle on the addition of 0·1 *N* NaOH to sodium oleate solutions, and is of the same form as that obtained with paraffin wax under the same conditions. It is seen that spreading occurs down to a concentration of 0·02 per cent. and, as found for paraffin wax, once a certain amount of caustic soda has been added, further additions have only a slight effect. The initial irregularities in the curve were not investigated as in the case of paraffin, but are most probably due to the same cause.

The action of alkali in increasing the surface tension of soap solutions is probably mainly due to the suppression of hydrolysis and of acid soap

formation[14, 15]. In the system paraffin wax/air/aqueous alcohol, for example, θ was almost unaffected by *p*H, although increase in surface tension brought about by increasing the percentage of water caused a corresponding increase in contact angle.

(3) *The Removal of Oils from Textile Fibres.* It is a natural extension of contact angle measurement in air to measurements where air has been replaced by an organic liquid. Such measurements have been extensively used by Rehbinder[5] in studying the flotation of minerals. He distinguishes two cases B_{21} and B_{12} which show a strong "static hysteresis." B_{21} represents a solid wetted by the liquid 1, to which has been added a drop of the liquid 2 whilst B_{12} is the converse of this. The method employed in the present investigation was slightly different, the textile fibre being coated with

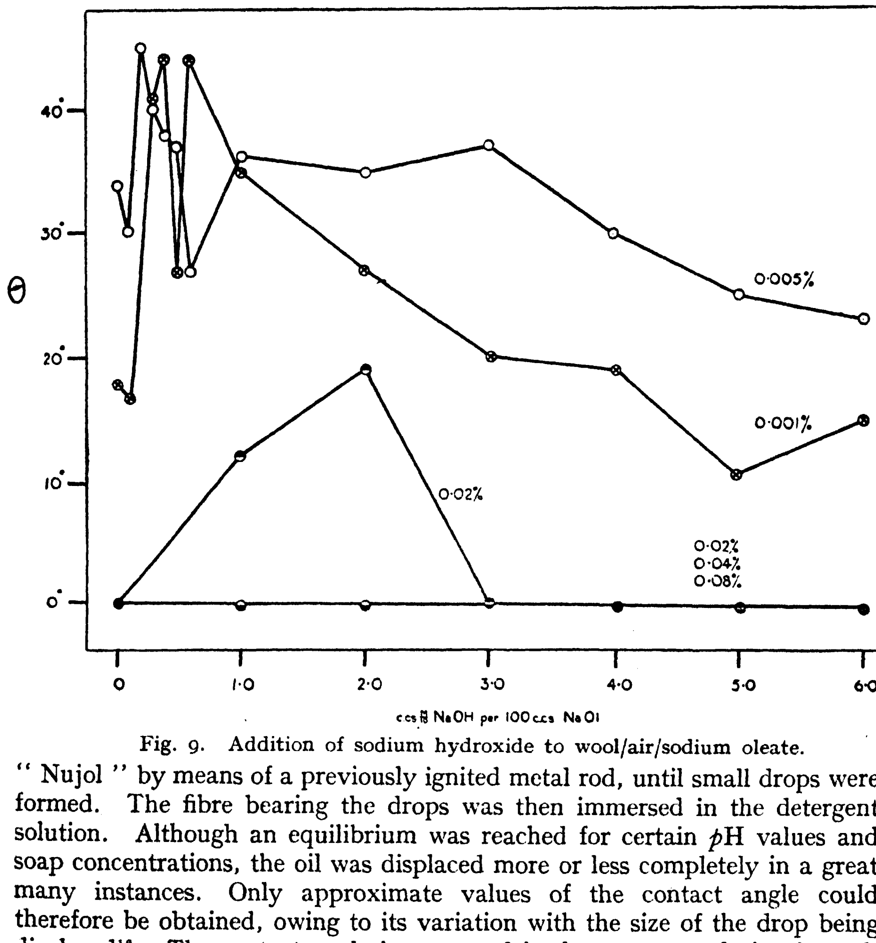


Fig. 9. Addition of sodium hydroxide to wool/air/sodium oleate.

"Nujol" by means of a previously ignited metal rod, until small drops were formed. The fibre bearing the drops was then immersed in the detergent solution. Although an equilibrium was reached for certain *p*H values and soap concentrations, the oil was displaced more or less completely in a great many instances. Only approximate values of the contact angle could therefore be obtained, owing to its variation with the size of the drop being displaced[16]. The contact angle is measured in the aqueous solution in each instance, being approximately zero when removal of the oil occurs. Over the *p*H range 7·5 to 12·2, 0·2 per cent. sodium laurate gave a contact angle in the region of 150° for wool and cotton, and 70° for cuprammonium rayon. With acetate rayon the "Nujol" drops left the fibre almost immediately at *p*H 11·0, after a minute at *p*H 12·0, and after 20-30 seconds at *p*H 9·0. Sodium oleate at the same concentration was much more efficient in removing the oil. From *p*H 9·0-10·5 removal of oil from wool was extremely rapid,

although above *p*H 11·0 a stable angle of 150° was formed. A similar effect was observed with cotton, most rapid removal occurring just below *p*H 10·0. At *p*H 9·0 the time of removal had increased from 20 to 60 seconds. Above *p*H 11·0 a contact angle of 40° still existed after two minutes. This minimum in the time taken for removal was even more pronounced in the case of cuprammonium rayon and occurred at the same *p*H. Acetate rayon again behaved differently, the time required for removal of the "Nujol" being negligible at *p*H 11·0 and gradually increasing to 60 seconds at *p*H 9·2.

Decreasing the concentration of sodium oleate to 0·02 per cent. greatly reduced its oil-removing efficiency. However, at *p*H 10·0 oil drops commenced to leave cuprammonium rayon and cotton fibres after one minute, but at *p*H 9·0 and 11·0, even after two minutes the contact angle had decreased only to 100°. In the case of acetate rayon there was in addition a slight tendency for the smaller oil drops to be removed after two minutes at *p*H 11·0.

A considerable number of experiments was made on the effect of alteration in the *p*H value of the solution in contact with the oil-coated fibre. In general, oil removal was as efficient when the soap solution was buffered initially to the optimum *p*H, as when that value was approached subsequently, from the acid or alkaline side, by the addition of alkali or acid salt respectively. At low soap concentrations however, where initial buffering always resulted in the production of a stable contact angle, removal of the oil drop could be brought about by first decreasing the *p*H until turbidity occurred, and then adding alkali. This is explained by the tendency of acid soap to collect at the oil-aqueous solution interface and dissolve in the oil, a process which could be clearly observed under the microscope in the case of particles separating from sodium laurate solutions at low *p*H values. Subsequent addition of alkali causes the formation of a local excess of soap on the interface, which is sufficient to free the oil drop from the fibre.

DISCUSSION OF RESULTS.

Surface tension of the Solid.

Antonow's Law may be expressed "if two liquids are partially miscible or non-miscible, the interfacial tension of the two phases consisting of the mutually saturated liquids is equal to the difference of the surface tensions of both these phases with regard to their mutual vapour phase." Comparison of the θ / concentration and θ/*p*H curves with the corresponding surface tension/concentration and surface tension/*p*H curves[4] indicates a similarity of form suggesting that, contrary to expectations, Antonow's Law holds at least qualitatively for the system paraffin wax/air/soap solution.

The decrease in free energy when a liquid is separated from a solid in a gas involves the surface energies of the two new surfaces formed, and the interfacial energy of the interface destroyed. Denoting by σ_{LG} and σ_{SG} the surface tensions of the liquid and solid respectively and by γ_{LS} the interfacial tension, the adhesional work, $-\varepsilon_{LS}$ is given by the equation

$$-\varepsilon_{LS} = \sigma_{LG} + \sigma_{SG} - \gamma_{LS} \qquad \text{..................(1)}$$

Hohn and Lange[17] have pointed out that the results obtained by Loman and Zwikker[18] indicate that the expression $\gamma_{LS} - [\sigma_{LG} - \sigma_{SG}]$ is dependent upon the nature of the solid only and independent of the liquid, but that the surface tension of the solid can only be calculated if a further empirical law

$$\sigma_{LG} - \sigma_{SG} = \gamma_{LS} \qquad \text{..................(2)}$$

also holds. This application of Antonow's Law however, even if its

theoretical basis in relation to solids is very uncertain, leads to a simplification of the conditions for spreading, and is supported at any rate qualitatively by the experimental results.

Thus substituting in (1) the value for γ_{LS} from (2), $\quad -\epsilon_{LS} = 2\ \sigma_{SG} \quad$ (3)
and the condition for spreading

$$2\ \sigma_{LG} \leqq -\epsilon_{LS}$$

reduces to $\quad 2\ \sigma_{LG} \leqq 2\ \sigma_{SG} \quad$ (4)

or in other words for spreading to occur the surface tension of the liquid must not exceed that of the solid.

Since only σ_{LG} can be readily measured it is necessary to obtain another relationship between σ_{SG}, σ_{LG} and γ_{LS} before Antonow's Law can be utilised. Although criticised by Green[19] on the ground that it applies only over the range of molecular forces, the simple theory of the contact angle leading to the expression $\gamma_{LS} - \sigma_{SG} + \sigma_{LG} \cos\theta = 0$ seems adequately supported by experimental facts. If one assumes a drop acted upon solely by phase boundary forces and gravity be neglected, this expression may best be derived by a method similar to that used by Lyons[20], considering the variation in the area of the solid/liquid interface with the area of the liquid/gas interface, when the volume of the drop remains constant. The principle of virtual work may then be applied to give $\gamma_{LS} - \sigma_{SG} + \sigma_{LG} \cos\theta = 0$ as the condition for equilibrium. Substituting the value of γ_{LS} from (2) it is found that $\quad 2\ \sigma_{SG} = \sigma_{LG}\ (1 + \cos\theta) \quad$ (5)

For paraffin wax and air using the values of the contact angle obtained with unbuffered sodium oleate solution over a concentration range of 0·003 – 0·5 per cent., σ_{SG} calculated from this formula is 25·5 ± 1 dyne/cm. (See Table 1.) At zero concentration of sodium oleate a value of 28·9 dynes/cm. was obtained.

Table 1.

Concentration of sodium oleate per cent.	Contact Angle degrees (Values interpolated from Fig. 2, in brackets)	Cosine of Contact Angle $\cos\theta$	Surface tension of liquid σ_{LG} dynes per cm. Interpolated.	σ_{SG} calculated as $\sigma_{LG}\ (1 + \cos\theta)/2$ dynes per cm.
0·003	(68)	0·375	36·2	24·9
0·004	65	0·423	35·3	25·1
0·005	(63)	0·454	34·4	25·0
0·006	60	0·500	33·6	25·2
0·007	(55)	0·574	32·8	25·8
0·008	50	0·643	32·0	26·3
0·009	(48)	0·669	31·4	26·2
0·010	46	0·695	30·8	26·1
0·011	43	0·731	30·3	26·2
0·012	40	0·766	29·9	26·4
0·02	34	0·829	27·2	24·9
0·04	25	0·906	25·7	24·5
0·05	0	1·000	25·7	25·7

This agreement was much less marked in the case of buffered solutions of constant soap concentration, the value obtained using 0·1 per cent. sodium oleate being 26 ±3 dynes/cm. over the range *p*H 12·0 to 7·4. Sodium laurate under the same conditions gave values ranging from 23·2 to 40·4 dynes/cm., but the calculated values of σ_{SG} always tended to rise with increase in the *p*H value of the solution. In the case of the σ_{SG} value for alcohol/water mixtures the value was 24 ±2 dynes per cm.

The wider variation found for buffered solutions is not unexpected for it is unlikely that the surface of the paraffin will remain uncovered by an adsorbed film of surface active substance, and it is probable that the composition of this film will change with the *p*H of the soap solution.

Nature of the Adsorption Layer. The application of Antonow's Law to the calculation of the free surface energy is unlikely to give the free surface energy of the paraffin wax surface lying beneath the adsorption layer, but rather that of the adsorbed layer itself. The calculated value is of the order of 25 ergs.cm.^{2} and tends to rise with increase in the *p*H of the solution. The new surface is therefore hydrophobic, that is, water would form a contact angle greater than 90° against this surface in air, and has in fact a free surface energy very similar to the values given in the International Critical

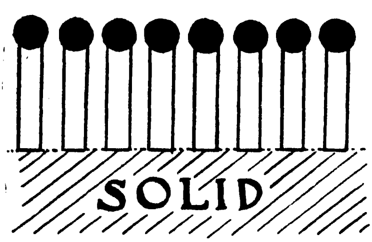


FIG. A

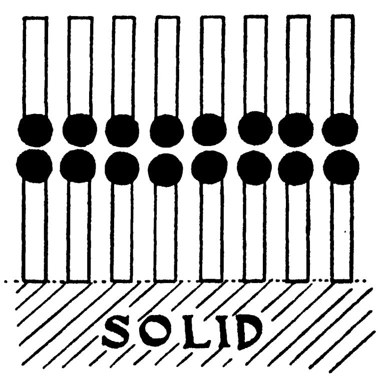


FIG. B

Tables for melted paraffin wax, or calculated from the contact angle made by water against solid paraffin wax, in air. The orientation is thus more likely to be as shown in Fig. B than in Fig. A. Lyons' conception of the formation at the surface of a soap solution of a bimolecular film composed of molecules oriented with their polar groups together is not therefore at variance with the experimental results. The wetting of paraffin by a surface active substance is not a direct antithesis to the flotation of a mineral. In the latter case an initially hydrophilic surface may be rendered hydrophobic by the adsorption of a hydrophobic film of the flotation agent ; in the former the character of the surface may remain unaltered, a hydrophobic adsorption layer being formed upon an already hydrophobic substrate. The wetting of the paraffin has therefore to be brought about by the decrease in the surface energy of the *liquid*, caused by adsorption at the air-liquid interface.

The variability of the product $\sigma_{LG}(1+\cos\theta)/2$ in the case of the buffered solutions is probably to be explained by a change in the nature of the adsorbed film on the solid.

Rehbinder[5] has shown that a straight line is obtained on plotting the concentration (c) of a surface active substance against a variable Z equal to $\frac{c}{Bo - B(c)}$, and has explained this relationship by deriving a theoretical expression for Z,

$$Z = a/(B_0 - B_1) + C/(B_0 - B_1)$$

B_0 is the cosine of the contact angle formed when the surface is free from any adsorption layer.

B_1 is the cosine of the contact angle made against a saturated adsorption layer. $B_{(0)}$ is the cosine of the contact angle at a concentration c, and a is the constant in Langmuir's adsorption equation

$$\Gamma/\Gamma_\infty = c/c+a$$

where Γ = adsorption at concentration c

Γ_∞ = saturated adsorption.

a can be shown to equal c_i the concentration at which the contact angle is 90°. As the value of c_j obtained with unbuffered sodium oleate is

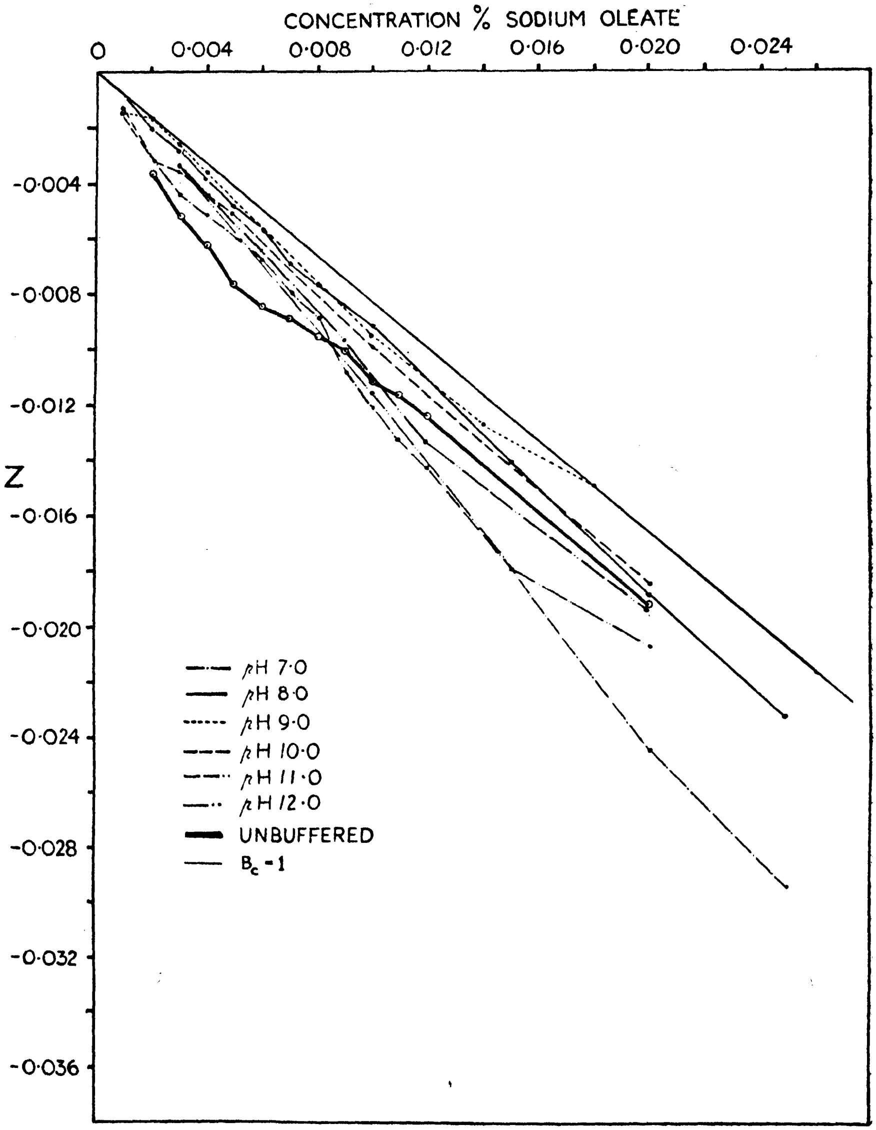


Fig. 10.

approximately 0.0004 per cent., even at 0.005 per cent. concentration the interface is 93 per cent. saturated. At greater concentrations the expression for Z will be approximately equal to $c/(B_0 - B_1)$, as $B_{(0)}$ will become constant and equal to B_1. It would be expected therefore that apart from a

very slight deviation at concentrations below 0·005 per cent., the plot of Z against C would give a straight line passing through the origin. It can be seen from Fig. 10 that this is approximately the case. The variations in the slopes of the lines for solutions of different *p*H values can be attributed to the variation in the nature of the adsorbed film. A more hydrophobic film will give a greater value for the contact angle, a lower value for $B_{(1)}$, and therefore a numerically greater value for Z. With the exception of the *p*H 7·0 line of which the anomaly is probably due to the separation of fatty acid in the solutions, the more alkaline solutions have greater values of Z for a given concentration, in accordance with expectation.

Applications. By choosing a point on the experimental θ / *p*H curve and calculating from its co-ordinates σ_{SG}, it has been found possible to construct a theoretical θ / pH curve by means of the expression

$$2\sigma_{SG} = \sigma_{LG}\,(1 + \cos\theta)$$

This has been done for a 0·1 per cent. solution of sodium oleate (Table II and Fig. 11), the σ_{LG} values being taken from previously published data[4]. The agreement is quite reasonable when the assumptions upon which the calculation is based are considered.

Table 2.

0·1 per cent. sodium oleate *p*H 10·3, σ_{LG} 26·4, cos θ=1, σ_{SG}=26·4 (calc.)

*p*H	σ_{LG}	$\cos\theta\ \left(=\frac{2\sigma_{SG}-\sigma_{LG}}{\sigma_{LG}}\right)$	θ
12·0	32·5	$\left(\frac{20·3}{32·5}\right)$	51°
11·0	30·4	$\frac{22·4}{30·4}$	42°
10·7	28·0	$\frac{24·8}{28·0}$	28°
9·0	26·4	1	0°
8·0	26·0	>1	0°
7·5	27·3	$\frac{25·5}{27·3}$	21°
7·0	30·6	$\frac{22·2}{30·6}$	43°

In the same way if the σ_{SG} value is calculated, the highest *p*H at which a soap solution of known concentration will spread over the solid may be predicted from the σ_{LG} / *p*H curves. Thus for 0·1 per cent. sodium oleate solution, the value of 26 dyne/cm. may be considered an average value for σ_{SG}. The σ_{LG}/*p*H curve indicates that the surface tension of the soap solution has dropped to 26 dyne/cm. between *p*H 11·0 and 10·0, and thus when the *p*H has decreased to this point the solution should spread over the paraffin. Experimentally the spreading is observed to commence in the region of *p*H 10·3.

A sodium laurate solution is even more affected by alkali than sodium oleate. Thus when a drop of unbuffered 0·2 per cent. sodium laurate solution was placed on a paraffin wax block it spread over the surface. On the addition of a trace of trisodium phosphate solution to the centre of the film so formed, the latter commenced to contract and had soon become an approximately hemispherical drop. The behaviour of a capillary system

formed by applying a solution of the wax in petroleum ether to filter paper, and then evaporating the ether by gentle heat, was slightly different. A drop of sodium laurate which had wetted out the paper did not retract from

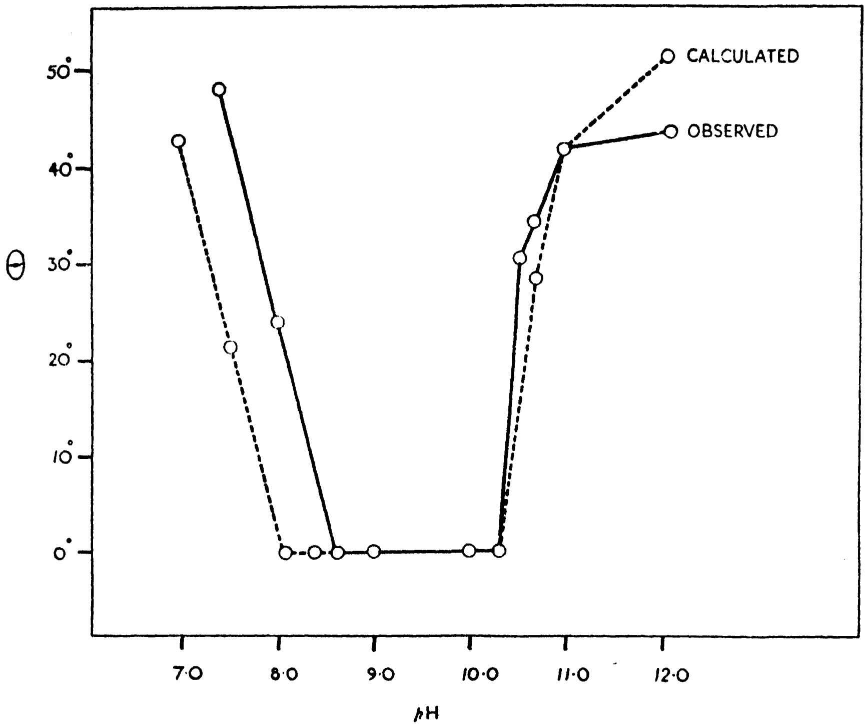


Fig. 11. Experimental and theoretical curves for paraffin wax/air/0·10% sodium oleate.

the capillaries upon addition of alkali, although an initially alkaline solution remained as a drop upon the surface of the waxed paper.

A more direct connection between capillary wetting and surface energies may be obtained if Antonow's Law is utilised. By substituting in Poiseuille's formula for flow in a capillary tube, the expression

$$dL/dT = 2R\,(2\sigma_{SG} - \sigma_{LG})\,\zeta/8\,L$$

is obtained if spreading does not occur, or $dL/dT = 2R\,\sigma_{LG}/8\,\zeta L$ if it does, where— L = distance penetrated.
ζ = viscosity of solution.
T = time.

R = radius of capillary, or, in the case of a fabric a constant depending upon the structure and distribution of the irregular capillary spaces which enable the latter to be considered as a single capillary[22].

In the case of penetration of a soap solution into a fabric it is impracticable to test the first expression owing to the considerable adsorption of the surface active substance and the low concentration necessary to secure non-wetting, but if concentrations above 0·1 per cent sodium oleate solutions are employed to wet cotton and the variation in ζ is neglected then for equal distances penetrated $dL/dT = K\sigma_{LG}$. This has been confirmed by some recent measurements made in this Laboratory[23] on the rate of penetration of a cotton fabric by sodium oleate solutions; and is also in agreement with the observations of Lederer[24] on penetration into filter paper. The formulae

obtained for rate of penetration show that for a hydrophobic capillary, decrease in the surface tension of the liquid *increases* the rate of capillary wetting up to the point at which spreading occurs, but further decrease in surface tension *decreases* the rate of capillary wetting.

In general, the capillary spaces in a soiled textile are filled with air, which must be displaced before a detergent can come into contact with the dirt upon the capillary wall. The qualitative experiments described earlier showed that it was necessary for the substrate to be wetted before an oily soiling was removed. The above considerations show in addition that if the wetting is increased to the point at which spreading occurs, the force available to drive the displacing liquid along the capillary will be correspondingly increased, the air rapidly displaced, and the detergent brought most effectively into contact with the soiling it is to remove.

SUMMARY

Measurements of the contact angle in the systems paraffin wax/air/detergent solution and wool/air/detergent solution have been carried out at 23° C. ±2°, using buffered solutions of pure sodium laurate and sodium oleate.

The angle has been shown to depend upon the surface tension of the detergent solution, and Loman and Zwikker's extension of Antonow's Law has been utilised to explain the results obtained.

The spreading of soap solutions on oiled and untreated textile fibres has also been studied and the *p*H of the detergent solution demonstrated to have an important effect upon the displacement of the oil. It is pointed out that the tendency of the detergent to spread over the substrate is as important a factor as its tendency to spread over the oil.

REFERENCES

[1] For example, Bartell and Jennings, *J. Phys. Chem.*, 1934, **38**, 495, and *Ind. Chem.*, 1927 onwards.
[2] A. F. Taggart, T. C. Taylor, and C. R. Ince. *Am. Inst. Min. Met. Eng. Transactions.* Milling Methods, 1930, p. 285.
[3] cf. Wark, *J. Phys. Chem.*, 1936, **40**, 661.
[4] J. Powney. *Trans. Faraday Soc.*, 1935, **31**, 1510.
[5] Rehbinder, Lipetz, Rimskaja and Taubmann, *Koll. Z.*, 1933, **65**, 268, gives references to previous work. *Koll. Z.*, 1933, **66**, 212, refers to the wetting of paraffin wax.
[6] Wm. Moore and S. A. Graham. *J. Agr. Res.*, 1918, **13**, 523.
[7] A. H. Nietz and R. A. Lambert. *J. Phys. Chem.*, 1929, **33**, 1460.
[8] Adam and Jessop. *J.C.S.*, 1925, **127**, 1863..
[9] Coghill and Anderson. *Bureau of Mines Tech. Paper*, 262, 1923.
[10] I. R. Kljatschko, *Koll. Z.*, 1936, **74**, 90.
[11] Rehbinder and Wenstrom. *Koll. Z.*, 1930, **33**, 145.
[12] Rehbinder, Lipetz and Rimskaja. *Koll. Z.*, 1933, **66**, 212.
[13] K. Kremnev and T. Papkova-Kwitzel. *Acta physico-chemica*, 1935, **3**, 451.
[14] Adam. *Trans. Faraday Soc.*, 1936, **32**, 653.
[15] H. L. Cupples. *Ind. Eng. Chem.*, 1936, **28**, 434.
[16] G. L. Mack and D. A. Lee. *J. Phys. Chem.*, 1936, **40**, 161.
[17] Hohn and Lange. *Phys. Z.*, 1935, **36**, 603.
[18] Loman and Zwikker. *Physica*, 1934, **1**, 1181.
[19] E. L. Green. *J. Phys. Chem.*, 1929, **33**, 921.
[20] Lyons. *J.C.S.*, 1930, 629.
[21] Lyons and Rideal. *Proc. Roy. Soc.*, 1929, **124**, 344.
[22] Peek and McLean. *Ind. Eng. Chem.* (Anal. Ed.), 1934, **6**, 85.
[23] See "Wetting and Detergency," London (1937), p. 185.
[24] E. L. Lederer. *Koll. Z.*, 1935, **72**, 267.

ACKNOWLEDGMENTS

The authors wish to express their thanks to the Director of Research for his helpful advice and criticism, and to the Council of the British Launderers' Research Association for permission to publish this work.

Received 16/3/37

17—YARN STRENGTH OF EGYPTIAN MIXINGS

By FRANK DUNKERLEY, A.T.I.
(Botanical Section, Ministry of Agriculture, Egypt)

SUMMARY

(1) The yarn strength of a 50 : 50 mixing of any two Egyptian cottons is near to the average yarn strength of the components spun unmixed.

(2) Cottons contribute their undiminished quota to the yarn strength of mixings proportional to the quantities present, however many components there may be to the mixing and whatever the proportions mixed.

(3) Even the asymmetrical structure produced by spinning a double roving yarn from odd roving bobbins is equal in strength to the mean of the components.

(4) Attention is drawn to the tendency of mixings to be slightly higher in strength than the average of components ; it is concluded that irregularity of staple (as distinct from wastiness) is not in itself a cause of weak yarn.

INTRODUCTION

Most agricultural crops vary in quality from season to season, and from one district to another, the Egyptian cotton crop being no exception. A very general habit of blending or mixing has therefore grown up both at the growers' and the spinners' end of the industry, in the effort to maintain uniform quality of the manufactured article.

The equable climate and constant water supply of Egypt minimise annual variation in quality as compared to that of most raingrown crops, and in Egypt it has probably always been the case that the majority of mixings were made up with an eye to some specified grade of cotton, but the components of the mixing were not always of the same variety. Since the introduction of Law No. 51 in 1934 the practice of mixing different varieties has been entirely prohibited except in the very low grades, when the bales must be marked "mixed." Spinners are thus assured of the identity of the cotton which they receive, yet there is ample scope for the Alexandria merchant to exercise his traditional skill in matching quality and grade of his type samples, and bulkings of half-a-dozen deliveries, all of the same variety, are not uncommon.

In making up mixings in a spinning mill, it will usually happen that many cotton fields have contributed to the material passing in, even when it is all of the same variety ; moreover, it is not unusual for spinners to include different varieties in their mixings. Since strength is the most important characteristic of cotton textiles, the question naturally arises, What is the effect on the average strength when all these deliveries differing in varying degree are mixed together by the merchant or spinner ?

Questions such as this came early to the fore in connection with researches on new cottons carried out by the Spinning-Test Mill of the Egyptian Ministry of Agriculture, but no answers were to be found in the technical literature dealing with Egyptian cotton. The experiments on mixings now to be recorded were conducted primarily with the object of simplifying these researches, but the results are of such wide general interest that they may well find useful application elsewhere.

In the experiments, sixteen Egyptian cottons of known unmixed origin were mixed together in various proportions, 2, 3, 4, . . . up to 14 cottons at a time. Using the spinning technique* described by Hancock[1] the mixtures were spun into 60's ring twist yarn, and tested for lea strength against the unmixed components, which were spun at the same time under strictly comparable conditions. The whole range of Egyptian cottons was represented, besides several new varieties as yet not commercially propagated; some 200 spinnings and 4,000 lea tests were involved in the work, which for the intended purpose may claim to be fairly comprehensive

Detailed results are listed into tables as follows:—

Table I: description of cottons and key to identity letters.
Table II: mixings of two components in equal proportions.
Table III: mixings of two components in unequal proportions.
Table IV: mixings of more than two components in equal proportions.
Table V: mixings of more than two components in unequal proportions.

The results of all these spinnings and testings may be summarised in one simple statement: *The lea strength of any Egyptian mixing is near to the average strength of all the samples in the mixing, weighted according to the amount of each sample present.* This rule is found to hold whether the staples mixed are long or short, fine or coarse, high grade or low grade, strong or weak; it holds whether there are few or many components in the mixing and whatever the proportions mixed; and each cotton contributes its undiminished quota to the yarn strength of the mixing. Some of the peculiar proportions quoted in the tables arose from an attempt to make up samples of predetermined mean staple length and hairweight using different components in suitable proportions; but these mixings fall in line with the general rule and are of no particular interest.

Besides the experiments described, in which mixings took place behind the card, a subsidiary experiment was carried out in which the cottons remained unmixed up to the final roving, and a mixed yarn was then produced by interchanging bobbins in the ring-frame creel (all the yarns were spun from double roving). As is usual, the two rovings drafted separately, and did not merge until they left the front roller nip and commenced twisting; nothing in any way abnormal was noticed either during spinning or in the spun yarn, although the yarn section was as asymmetrical as it could be Even in the case of a mixture of the longest and shortest Egyptian cottons available, the strength of the mixing was still found to be equal to the average of the two components spun separately. (See Table VI.)

DISCUSSION OF RESULTS

Casablancas Apron Drafting System is fitted to all the frames except the drawframe at the Spinning-Test Mill at Giza, where these yarns were spun. This drafting system has the advantage for spinning-test work of not requiring roller re-settings over a wide range of staple lengths, and samples as different as Sakha 4 and Ashmouni can be seen drafting simultaneously at near to optimum conditions on adjacent spindles. As far

* After sampling, each cotton is handfed to a card covered on cylinder, flats, and doffer, with Roubaix self-stripping wire. Resulting sliver, of 0·2 hank, is made into a lap of 80 slivers to be carded a second time. Mixing is done at this stage; for 50:50 mixings the lap is 40 slivers of each component. Second card sliver is 0·26 hank, there are three heads of drawing, and the slubbing is 1·30 hank. Double roving at inter and rover give roving of 8·30 hank, and the yarns are all ring-spun 60's of 3·6 twist factor.

as ordinary cottons are concerned, good agreement is found between testings of yarns spun on this system and testings from more normal systems elsewhere, the evidence being presented in Hancock's paper[2] previously quoted. It is, however, reasonable to ask if parallel results would be obtained from the different drafting systems when dealing with the mixings of different cottons now under discussion.

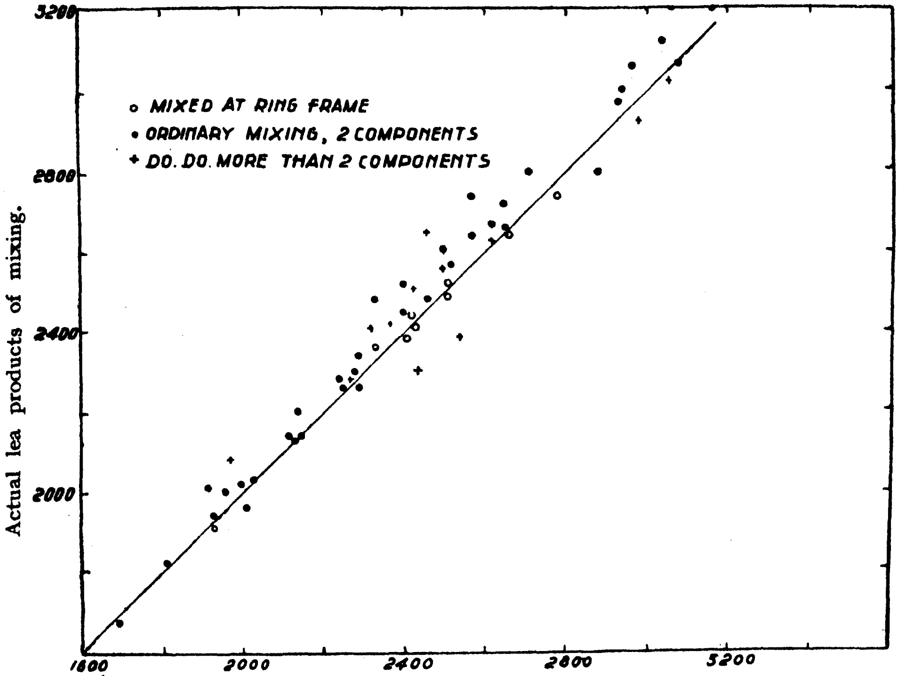
The question hinges chiefly on the effect of staple length irregularity, and it might be argued that the irregular staples would be more efficiently drafted by the apron system. Actually no such differential behaviour has been noticed, although differences in staple irregularity have occurred in unmixed samples which have been compared by the two systems. In point of fact, the irregularity of staple length* within any normal sample is so great that the mixing of samples together can cause only a relatively small increase in length irregularity. For example, the irregularity (σ per cent.) of staple length of a long Sakha 4 cotton was found to be 29 per cent., and of a short Ashmouni cotton, 27 per cent.; these were mixed in equal proportions and the length irregularity of this extreme mixing was 30 per cent., barely higher than that of the more irregular component. That mixings are more irregular is not of course denied, and this applies to other characters besides staple length, but the increase in irregularity is perhaps less than is generally imagined. Direct experiment is awaited to confirm if there is any differentiation between these mixed cottons on different drafting systems, but it appears likely that substantially parallel results to those recorded would be obtained on normal drafting systems working at optimum performance, except perhaps in the case of a few extreme mixings which we deliberately included as examples of *reductio ad absurdum*.

It has long been accepted by cotton breeders that regularity of staple was amongst the spinners' primary requirements; but we had proved even before this Mixing Experiment was begun that such differences in length irregularity as normally occurred between high grade cottons were of small importance compared to other factors. The further fact now shown is that when cottons of equal strength but different length are mixed, the mixture is not depreciated in strength though more irregular in staple. It is probably the association of wasty cotton with low grade that has given rise to complaint; the essential feature of low grade is its inclusion of damaged bolls—bolls damaged in the field, chiefly by the boll worm—and besides containing impurities, much of this cotton is short or immature. It is now clear that this form of wastiness is quite different from the straightforward case of irregularity.

As illustrated in Fig. 1 and in the tables, there is a pronounced tendency for the mixings to be slightly *stronger* than the weighted average of the components, amounting to nearly 2 per cent. on the average of all our samples. Two of the mixings showed as high a gain as 6 per cent., but no cotton showed consistent high gains and the high values probably arise from random variations. At any rate, there is found to be a slight gain on balance due to the practice of mixing Egyptian cottons, and this through accumulated impressions on many active minds, may have assisted in the universal prevalence of the practice.

---

* Calculated as the root-mean-square deviation from the mean hair length, expressed as a percentage of this length, using the Balls Sorter Diagram for the distribution.



Weighted average lea product of components :—

Fig. 1. Relation between actual strength of mixings, and the strength value calculated from the components. If each component cotton added its exact strength quota to the mixing, all points would lie on the equality line drawn ; actually there is a strong tendency for the points to lie above the line, indicating a net gain in strength due to mixing.

APPLICATION OF RESULTS TO SPINNING-TESTS

Whether or not Casablancas agrees with other drafting systems, the investigation has been very fruitful of results as applied to the routine at Giza. In common with the bulk of the commercial crop, our experimental growings are harvested in two portions, and the average quality was at first determined from the results of two separate spinnings. It is now seen to be feasible to spin a mixing of the two pickings in proportion to their respective yields, thus obtaining an over-all value of the crop quality from one spinning instead of two, leading to an economy of three or four hundred spinnings per year in the research routine. Similarly, replicated growings of series of varieties in many localities may be bulked by varieties, avoiding the necessity for separate spinnings of every sample as heretofore.

A very useful application of the mixing principle has been in the bulking together of large numbers of samples of the commercial crop. Testings on these are carried out by the Spinning-Test Mill every year on all the main Egyptian varieties, and enable the Research Departments to keep a finger on the pulse of the crop as a whole. The survey involves the collection of about 300 samples, and would be a serious labour if they all had to be spun separately ; but by means of bulkings about 36 spinnings suffice to give all the necessary information, the work is carried out quickly, results are available early in the season, and prompt action can be taken where desirable.

Table I. Identity Letters and Descriptions of the Cottons.

Identity Letter.	Sample and Grade.	General Description.
A	Giza 26B F.G.	The strongest type of cotton grown in Egypt, from a cross between a Sakel type and a Sea Island type. Commercially available in small quantities.
a	Ditto. ...	Another example of Cotton A. Reputedly identical but actually slightly longer, finer, and weaker.
B	Sakha 4 F.G.	A long staple cotton of light shade and good lustre ; as a type it is usually slightly below Sakel in strength, but this example is stronger.
C	Sakel F.G. ...	The best known Egyptian long stapled cotton, now fast dying out. This example is a typical good quality high grade.
C_2	Sakel G. ...	A second picking of Sakel, shorter and finer than C but of good strength.
C_3	Sakel F.G.F.	A lower grade of abnormally low strength.
D	New Hybrid F.G.	This is a cross between a Sakel type and Giza 7. It is peculiar in being stronger than would be expected from the staple characters. (It will be noted that this sample is 760 units stronger than the F.G.F. Sakel, although of similar staple.)
E	Giza 7 ... F.G.	A good quality staple and a plant with special agricultural merits. This cotton, also, is stronger than would be expected.
F	Giza 23 ... F.G.	A non-commercial cotton similar in lint type to Giza 12 (below). The coarseness of staple brings the strength down in spite of length.
F_2	Giza 23 ... F.G.F.	A second picking of sample F.
G	Super Giza 3 F.G.	An improved seed stock from Giza 3 (below). It is an Upper Egyptian cotton descended from an Ashmouni parent.
H	Giza 12 F.G.	A rather weak example of a new dark-shaded cotton now coming onto the market.
H_2	Giza 12 F.G.F.	A second picking of sample H.
J	Giza 3 F.G.	From standard seed stock, grown in Upper Egypt. An example somewhat finer than usual.
K	Ashmouni G./F.G.	A typical Uppers in every way.
K_2	Ashmouni F.G.F.	A second picking of sample K, it is rather longer than usual.

Table II. 50:50 Mixings only

Identity Letter.	Taker-in Waste % (of the Components).	Staple Length.	Hair Weight.	Lea Product.	Mixing Lea Product.	Mean of the Components	Deviation % from Mean.
A	2·4	25·5	130	3290	—	—	—
mixed with							
B	2·2	24·5	125	3035	3205	3160	1·5
C_3	5·0	23	140	2020	2720	2650	2·5
E	3·8	23·5	148	2570	2970	2930	1·5
a	2·4	26	125	3185	—	—	—
mixed with							
C	2·1	25	131	2990	3075	3085	0
F	3·4	23·5	168	2235	2805	2710	3·5
B	2·2	24·5	125	3035	—	—	—
mixed with							
A	2·4	25·5	130	3290	3205	3160	1·5
H	3·5	22	165	2265	2665	2650	·5
J	3·9	22·5	147	2020	2570	2525	2
K	5·2	20	183	1760	2450	2400	2
K_2	7·4	21	168	1635	2480	2335	6

Table II (continued) **50:50 Mixings only.**

Identity Letter.	Taker-in Waste % (of the Components).	Staple Length.	Hair Weight.	Lea Product.	Mixing Lea Product.	Mean of the Components.	Deviation % from Mean.
C	2·1	25	131	2990	—	—	—
mixed with							
a	2·4	26	125	3185	3075	3085	0
C_2	3·5	23·5	121	2915	2990	2950	1
D	3·0	23·5	142	2780	2805	2885	−3
H	3·5	22	165	2265	2675	2625	2
H_2	5·7	22·5	151	2015	2615	2500	4·5
K	5·2	20	183	1760	2425	2375	2
C_2	3·5	23·5	121	2915	—	—	—
mixed with							
C	2·1	25	131	2990	2990	2950	1
F	3·4	23·5	168	2235	2745	2575	6
H_2	5·7	22·5	151	2015	2485	2465	1
C_3	5·0	23	140	2020	—	—	—
mixed with							
A	2·4	25·5	130	3290	2720	2650	2·5
E	3·8	23·5	148	2570	2345	2295	2
D	3·0	23·5	142	2780	—	—	—
mixed with							
C	2·1	25	131	2990	2805	2885	−3
H_2	5·7	22·5	151	2015	2525	2400	5
E	3·8	23·5	148	2570	—	—	—
mixed with							
A	2·4	25·5	130	3290	2970	2930	1·5
C_3	5·0	23	140	2020	2345	2295	2
J	3·9	22·5	147	2020	2260	2295	−1·5
F	3·4	23·5	168	2235	—	—	—
mixed with							
a	2·4	26	125	3185	2805	2710	3·5
C_2	3·5	23·5	121	2915	2745	2575	6
F_2	6·1	23	156	2075	2145	2150	0
H	3·5	22	165	2265	2260	2250	·5
J	3·9	22·5	147	2020	2140	2125	1
K	5·2	20	183	1760	2020	2000	1
K_2	7·4	21	168	1635	1945	1935	1
F_2	6·1	23	156	2075	—	—	—
mixed with							
F	3·4	23·5	168	2235	2145	2150	0
G	3·1	23·5	154	2300	—	—	—
mixed with							
K	5·2	20	183	1760	2030	2030	0
K_2	7·4	21	168	1635	2000	1965	2
H	3·5	22	165	2265	—	—	—
mixed with							
B	2·2	24·5	125	3035	2665	2650	·5
C	2·1	25	131	2990	2675	2625	2
F	3·4	23·5	168	2235	2260	2250	·5
H_2	5·7	22·5	151	2015	2130	2140	−·5
J	3·9	22·5	147	2020	2205	2140	3
K	5·2	20	183	1760	1965	2010	−2
H_2	5·7	22·5	151	2015	—	—	—
mixed with							
C	2·1	25	131	2990	2615	2500	4·5
C_2	3·5	23·5	121	2915	2485	2465	1
D	3·0	23·5	142	2780	2525	2400	5
H	3·5	22	165	2265	2130	2140	−·5

Table II (continued).

Identity Letter.	Taker-in Waste %	Staple Length.	Hair Weight.	Lea Product.	Mixing Lea Product.	Mean of the Components.	Deviation % from Mean.
	(of the Components.)						
J	3·9	22·5	147	2020	—	—	—
mixed with							
B	2·2	24·5	125	2035	2570	2525	2
E	3·8	23·5	148	2570	2260	2295	−1·5
F	3·4	23·5	168	2235	2140	2125	1
H	3·5	22	165	2265	2205	2140	3
K	5·2	20	183	1760	—	—	—
mixed with							
B	2·2	24·5	125	3035	2450	2400	2
C	2·1	25	131	2990	2425	2375	2
F	3·4	23·5	168	2235	2020	2000	1
G	3·1	23·5	154	2300	2030	2030	0
H	3·5	22	165	2265	1965	2010	−2
K_2	7·4	21	168	1635	1670	1695	1·5
K_2	7·4	21	168	1635	—	—	—
mixed with							
B	2·2	24·5	125	3035	2480	2335	6
F	3·4	23·5	168	2235	1945	1935	1
G	3·1	23·5	154	2300	2000	1965	2
K	5·2	20	183	1760	1670	1695	1·5

NOTE—All mixings in the above table are of equal parts by weight. Staple lengths are given as $\frac{1}{16}$th-inch units. Lea product is the figure obtained by multiplying lea strength in lbs. by the actual counts, which are 60's.

Table III. Unequal Proportions of two components

Identity Letter. Ratio.	Taker-in Waste %	Staple Length.	Hair Weight.	Lea Product.	Mixing Lea Product.	Mean of the Components.	Deviation % from Mean.
	(of the Components).						
a 100	2·4	26	125	3185	—	—	—
mixed with							
H 34 : 66	3·5	22	165	2265	2640	2570	3
K 95 : 5	5·2	20	183	1760	3205	3065	5
K 90 : 10	—	—	—	—	3125	3040	3
K 85 : 15	—	—	—	—	3060	2970	3
E 100	3·8	23·5	148	2570	—	—	—
mixed with							
K 20 : 80	5·2	20	183	1760	2010	1925	4·5
G 100	3·1	23·5	154	2300	—	—	—
mixed with							
K 90 : 10	5·2	20	183	1760	2280	2245	2
K 10 : 90	—	—	—	—	1820	1815	0
H 100	3·5	22	165	2265	—	—	—
mixed with							
a 66 : 34	2·4	26	125	3185	2640	2570	3
K 100	5·2	20	183	1760	—	—	—
mixed with							
a 5 : 95	2·4	26	125	3185	3205	3065	5
a 10 : 90	—	—	—	—	3125	3040	3
a 15 : 85	—	—	—	—	3060	2970	3
E 80 : 20	3·8	23·5	148	2570	2010	1925	4·5
G 10 : 90	3·1	23·5	154	2300	2280	2245	2
G 90 : 10	—	—	—	—	1820	1815	0

NOTE—The first figure under "Ratio" is the proportion of the sample at the head of the group.

Table IV. Equal Proportions of more than two components.

Identity Letters.	Proportions.	Mixing Lea Product.	Mean of Components.	Deviation % from Mean
A C_3 E	33 33 33	2630	2625	0
A E K	33 33 33	2390	2540	−6
a B C C_2	25 25 25 25	3020	3050	−1
F H K K_2	25 25 25 25	2080	1975	5
a B C C_2 F H K K_2	12·5 % of each	2565	2500	2·5
B C C_3 D F F_2 H H_2 J K	10% of each	2415	2320	4
a B C C_2 C_3 D E F F_2 H H_2 J K K_2 ...	7% of each	2510	2420	3·5

Table V. Unequal Proportions of more than two components.

Identity Letters.	Proportions.	Mixing Lea Product	Mean of Components.	Deviation % from Mean
A B G	31 50 19	2935	2980	−1·5
D F J	56 22 22	2660	2470	7·5
B D J H	16 15 39 30	2425	2370	2·5
C C_2 K K_2	29 29 30 12	2310	2445	−5
B C F_2 H_2	12 12 38 38	2280	2275	0

Table VI. Mixings at the Ring Frame Creel. 50 : 50 Mixings.

Identity Letters.	Lea Product of Mixing.	Mean of Components.	Deviation % from Mean.
C_2 D	2740	2780	−1·5
B G	2645	2665	−1
D G	2520	2510	·5
C_2 F	2490	2515	−1
A K_2	2440	2420	1
A K	2410	2435	−1
E H	2385	2410	−1
B K_2	2360	2335	1
C_3 E	2305	2285	1
C_3 H	2140	2155	− ·5
F K	1910	1930	−1

NOTE—The " Mean of Components " is calculated from the results of repeat spinnings done at the same time as the mixings.

REFERENCES

[1] A Spinning Procedure for Cotton Samples, H. A. Hancock. *J. Text. Inst.*, 1937, 28, T161.

[2] *Ibid.*

Botanical Section, Ministry of Agriculture,
Orman, Egypt.

Received 25/5/37

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

18—THE ABSORPTION OF WATER BY CELLULOSE AND CELLULOSE COMPOUNDS

By J. TANKARD, M.Sc., A.Inst.P., A.T.I.

CONTENTS

I. INTRODUCTION

The fact that the absorption of water by cellulose and cellulose compounds is a somewhat complex process has been recognised for a long time, and many experiments have been made to obtain precise information as to the nature of that process.

H. F. Coward and L. Spencer (*J. Text. Inst.*, 1923, **14**, T28), using a specially designed centrifuge, made a comparison between the rates of removal of water from cotton fibres and from glass wool, and deduced from their results that a few minutes centrifuging with a centrifugal acceleration of the order of 2,000 times that of gravity sufficed to reduce the amount of inter-fibrillar liquid to 5-10 per cent. of the weight of the fibres themselves. Under the above conditions, however, cotton retained about 50 per cent. of its weight of water, and it was, therefore, concluded that the greater part of this water must be held within the body of the cotton fibres themselves.

W. L. Balls ("Studies of Quality in Cotton," Macmillan and Co., 1928, p.32), pointed out that the work of F. P. Slater (*Proc. Roy. Soc. B.*, 1923), on the effect of changes in humidity on the electrical conductivity of cotton fibres provided evidence of the existence of distinct phases in the process of absorption of water by cotton. The curve Log. Conductivity/Relative Humidity showed very distinct kinks at 38-42 per cent. Relative Humidity, and at about 15 per cent Relative Humidity. Later work on the effect of changes in humidity on the cross-sectional area of cotton fibres showed that kinks occurred in the curve Cross-sectional Area/Relative Humidity at 15 per cent., 40 per cent., 77 per cent., and 90 per cent. Relative Humidity.

These values, according to Balls, correspond to the boundaries between the distinct phases, at least five in number, in the process of absorption of water by cotton. These phases he designated provisionally as follows:—

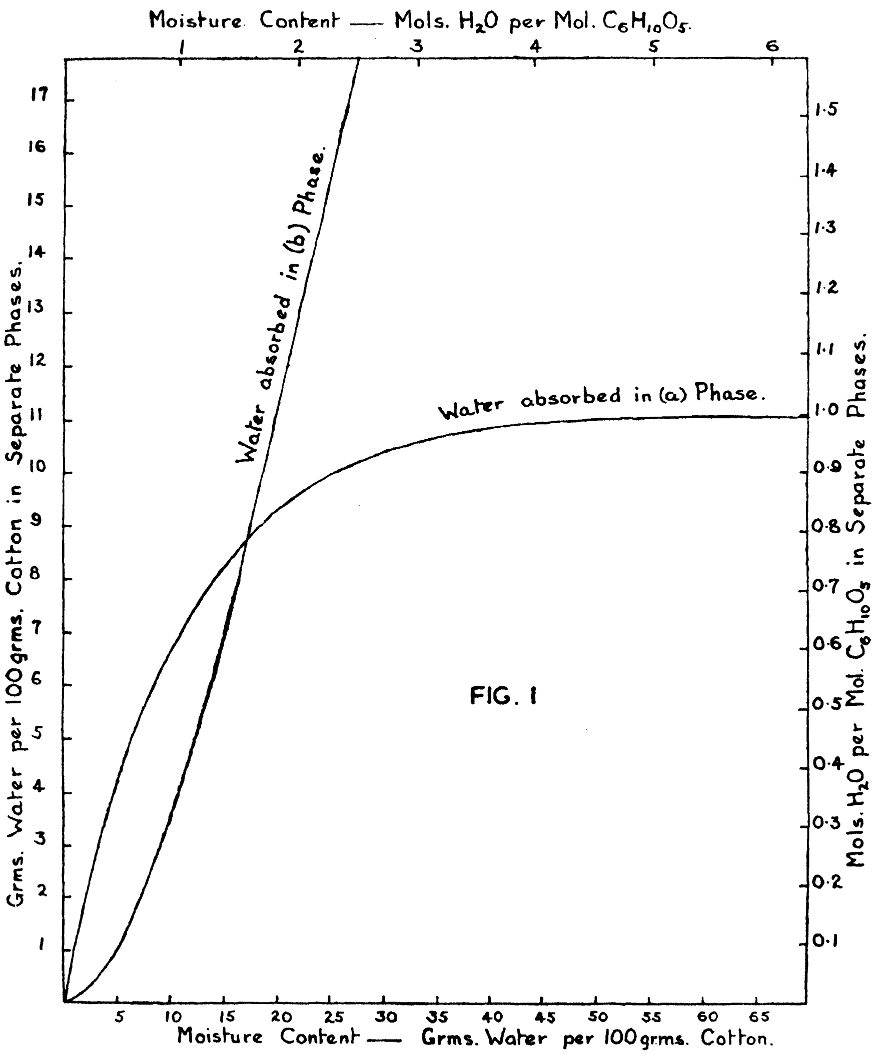
0-15	per cent.	Relative	Humidity	...	Phase of	chemical hydration.
15-40	,,	,,	,,	...	,,	mono-polar absorption.
40-77	,,	,,	,,	...	,,	tri-polar absorption.
77-90	,,	,,	,,	...	,,	molecular association.
Over 90	,,	,,	,,	...	,,	capillarity.

A. R. Urquhart and A. M. Williams (*J. Text. Inst.*, 1924, **15**, T433), as a result of experiments on the absorption and desorption of water by soda-boiled cotton at 25°C., put forward an explanation of the hysteresis effect exhibited by cellulose, based upon a theory of the capillary structure of cellulose. According to this theory, cellulose was regarded as an inelastic gel, i.e., as consisting of micelles held together by their mutual attractions, the spaces between the micelles forming a network of capillaries or fine pores. On exposing a sample of cotton to water vapour, water molecules were considered to be adsorbed on the micellar surfaces, ultimately uniting to form a column of water in a capillary space, the smallest capillaries being filled first.

In a later paper, Urquhart (*J. Text. Inst.*, 1929, **20**, T215) pointed out that unpublished work carried out by Collins at the Shirley Institute (British Cotton Industry Research Association) had shown that cellulose is an elastic gel which increases steadily in volume as it absorbs water. The previous explanation of the hysteresis effect exhibited by cotton, based upon the theory that cellulose was an inelastic gel, was, therefore, untenable. Urquhart, therefore, suggested that the hydroxyl groups of the cellulose molecule are the chief points of attachment for water molecules. This he regarded as probable in view of the known high residual affinity of the –OH group, and the fact that in the case of cellulose acetate, in which the number of such groups is reduced, the amount of water adsorbed from an atmosphere of any given humidity is much less than in the case of cellulose itself.

S. E. Sheppard and P. T. Newsome (*J. Phys. Chem.*, 1929, **33**, p.1817) have also studied the hysteresis effect shown by the absorption and desorption isotherms of cellulose and its derivatives, and they agree with Urquhart in regarding the hydroxyl groups of the cellulose molecule as being the principal points of attachment for adsorbed water molecules. They point out that hydrate cellulose, i.e., cellulose regenerated from cuprammonium solution or cellulose from de-esterified cellulose acetate, absorbs water to a much greater degree than cellulose itself. This is attributed to the fact that in hydrate cellulose the hydroxyl groups of the cellulose molecule are less mutually satisfied than they are in cellulose, so that their attraction for foreign polar molecules is increased. In the case of cellulose acetate, the replacement of the hydroxyl groups by acetyl groups causes a reduction in the amount of water absorbed from an atmosphere of given humidity. Sheppard and Newsome point out, however, that the complete acetylation of cellulose to the tri-acetate does not reduce the amount of water absorbed to as low a value as might have been expected, and they suggest that this fact, together with other available evidence, indicates that a considerable part of the total amount of water absorbed by cellulose and its compounds must be due to inter-micellar adsorption in ultra-microscopic capillary spaces or micropores.

F. T. Peirce (*J. Text. Inst.*, 1929, **20**, T133-T150), as a result of observations on the rigidity of cotton fibres, assumed that moisture is present in cotton fibres in two distinct phases, in one of which (a), molecules of water



ABSORPTION OF WATER BY COTTON. (PEIRCE).

are associated with molecules of cellulose as in a chemical compound, whilst in the other phase (b), the water molecules are retained in a looser manner by physical forces operating at the surface of the material. Upon this assumption he developed mathematical formulae from which the amount of water in each of the two phases can be calculated. These quantities are shown graphically in Fig. 1. It will be noticed that according to this theory the maximum amount of water which can be absorbed in the first phase (i.e., as in a chemical compound) is 11·1 per cent., corresponding to one molecule of water per molecule of cellulose.

S. Oguri (*J. Soc. Chem. Ind. Japan*, 1932, **35**, 507B-511B), as a result of experiments on the velocity of sorption of water by cellulose has suggested that this sorption takes place in at least two stages, the velocity of sorption in each stage being represented fairly well by the equation

$$dx/dt = k(x_\infty - x),$$

where x and x_∞ denote the amounts of water present at time t and at equilibrium respectively, and k is a constant. In Fig. 2, which is copied from Oguri's paper, the curves have been drawn to satisfy the above equation, and the points marked represent experimental results.

E. A. Filby and O. Maass (*Can. J. Res.*, 1932, **7**, p. 162) determined the specific volume of cellulose and of the system cellulose-water vapour, and from the results obtained they calculated the apparent density of the absorbed water. For moisture contents up to about 5 per cent. the apparent density was nearly constant at a value about 2½ times that of ordinary water ; with further increase of the moisture content the apparent density decreased, becoming normal at about 8 per cent. moisture content. They concluded as a result of their experiments that when water is absorbed by cellulosic material it first combines chemically, with contraction of the system, and that further addition of water increases the cellulose surface, and consequently the contraction, until finally normal liquid water begins to fill the capillaries of the cellulose.

Sheppard (*Trans. Far. Soc.*, 1933, **29**, p.77) has confirmed the ideas advanced in his previous paper (with Newsome) and suggested that the first stage in the absorption of water by cellulose (up to about 5 per cent. for native cellulose, and 7 per cent. for hydrate cellulose) is an attachment of water molecules to $-OH$ groups. Beyond this stage the water is considered to be held by capillary condensation and in inter-micellar spaces of sizes of the order 15-500 A.U.

G. Champetier (*Anal. Chim.*, 1933 (X), **20**, pp. 5-96), by the study of the ternary systems cellulose-water-sodium thiosulphate, and cellulose-water-pyridine, has determined experimentally the amount of water which may be regarded as entering into chemical combination with cellulose. His results indicate the existence of two hydrates of cellulose ; the first, which is formed by ordinary cellulose, having a formula $(C_6H_{10}O_5)_2.H_2O$; and the second, formed by mercerised cellulose, having a formula $C_6H_{10}O_5.H_2O$.

W. D. Bancroft and J. B. Calkin (*Text. Res.*, 1934, **4**, p.371), as a result of experiments on the removal of water from cellulose by centrifuging, have come to the conclusion that stoichiometric hydrates of cellulose do not exist. This conclusion seems to be based primarily upon the well-known fact that when water is removed, at constant temperature, from a substance such as copper sulphate which gives several distinct hydrates, the pressure remains constant during the transition from one hydrate to the next, and then undergoes a sudden decrease as the process of transition to another hydrate commences. The graphical representation of this process gives a stepped curve similar to that shown in Fig. 3.

Bancroft and Calkin point out that when the results of their experiments on cellulose are represented graphically by plotting Moisture Retained/Time of Centrifuging, a smooth curve is obtained. It seems obvious, however, that no step could be expected in such a curve until a point was reached corresponding to the formation of a hydrate. According to Champetier's results this would be at a value of 5·5 per cent. moisture. The lowest value

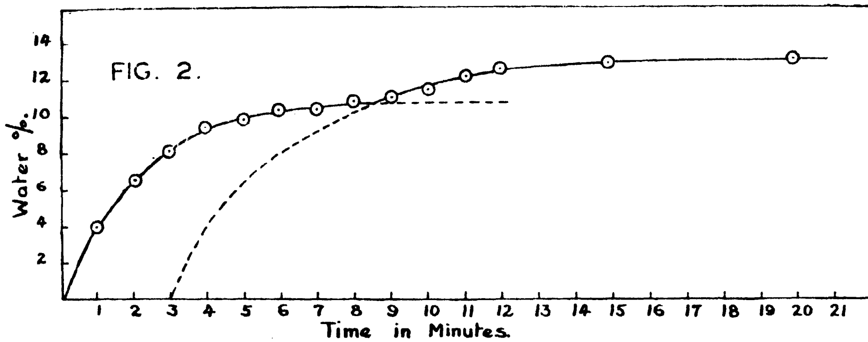


FIG. 2.

VELOCITY OF SORPTION OF WATER BY CELLULOSE. (OGURI).

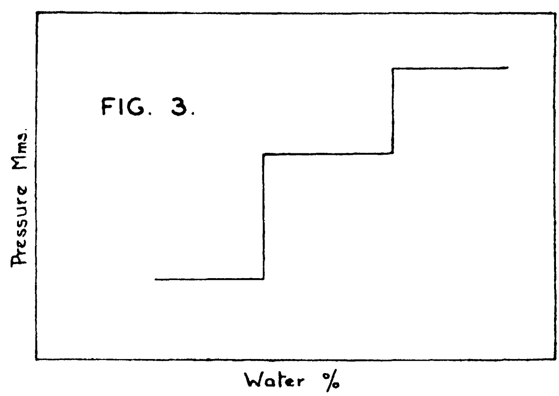


FIG. 3.

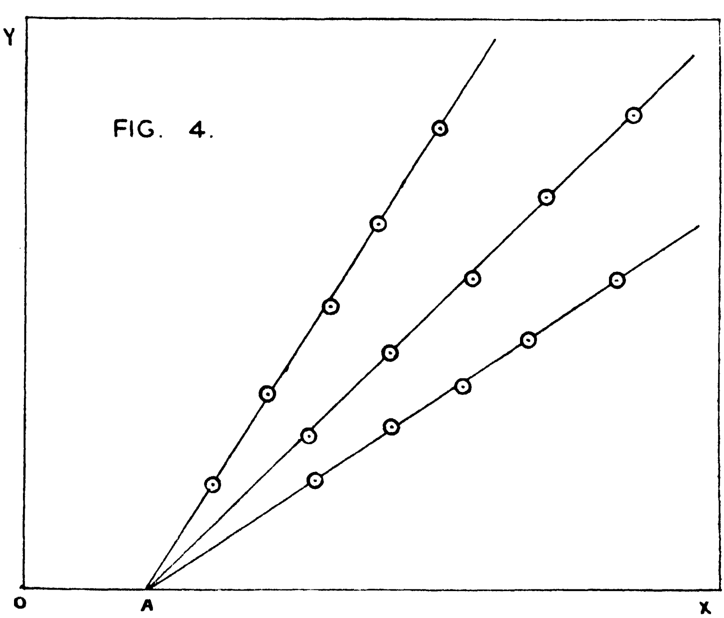


FIG. 4.

obtained by Bancroft and Calkin, however, was approximately 12 per cent. moisture.

Reference has already been made to experiments made by a number of workers to study the absorption and desorption of water by cellulose. These workers have determined the moisture content of samples of cotton in equilibrium with atmospheres of different vapour pressures at constant temperature. In these experiments moisture contents below 1 per cent. were recorded, but the curves Moisture Content/Vapour Pressure do not show a step such as that exhibited in Fig. 3. It is, however, unlikely that such a stepped curve would be obtained with cellulose if the absorption of water by cellulose occurs in two phases simultaneously, as has been suggested by some workers.

E. Burlet (*Bull. Lab. d'Analyses et Récherches Industrielles, Roubaix,* 1934, No. 22, pp. 4-10, No. 23, pp. 11-19), has suggested that the absorption of water by textile materials occurs in two stages. The first stage he describes as a stage of rapid superficial regain, and the second as a stage of slow deep absorption. It is not clear, from the details given, whether there is any other evidence for this suggestion than the well-known fact that when a sample of textile material is transferred from one atmosphere to another of higher humidity the absorption of water is rapid at first, but proceeds more and more slowly as the system approaches equilibrium.

It seems to be fairly generally agreed, therefore, that water absorbed by cellulose and cellulose compounds exists in at least two phases, the first being a phase of chemical combination between the water molecules and the hydroxyl groups of the cellulose molecule, and the second a phase of capillary absorption.

A number of workers seem to regard the absorption of the chemically combined water as constituting the first stage ; the second stage, i.e., that of capillary absorption, not commencing until the first stage has been completed, or at least until it has almost reached completion. On the other hand, it is considered by some that the absorption occurs simultaneously in both phases.

In the present series of experiments, the method of Champetier has been used to determine the " water of hydration " (i.e., the amount of water which may be regarded as entering into chemical combination) of cellulose and a number of cellulose derivatives.

II. THE DETERMINATION OF WATER OF HYDRATION

(a) Outline of Champetier's Method

The method of determination of water of hydration of cellulose adopted by Champetier is based upon the technique employed by Schreinemakers for the determination of the composition of double salts (*Z. phys. Chem.* II (1893), p.81).

Champetier studied the ternary systems cellulose-water-sodium thiosulphate, and cellulose-water-pyridine ; sodium thiosulphate and pyridine being chosen as substances which most satisfactorily fulfil the following necessary conditions:

(a) they do not combine with cellulose ;
(b) they do not produce hydrolysis or degradation of the cellulose ;
(c) they can be easily and accurately estimated.

Cellulose, after being allowed to attain equilibrium in the aqueous solution, was submitted to a gradually increasing pressure. Samples were

taken at intervals during the application of pressure, and their composition determined. The composition of these samples could be represented graphically by means of triangular co-ordinates, but a simpler method was adopted using rectangular co-ordinates, the composition of the various pressed samples being expressed in terms of a constant quantity of cellulose. This is illustrated in Fig. 4, in which each point represents a single pressed sample, the amounts of water and of sodium thiosulphate (or pyridine) associated with the samples being measured along the axes OX and OY respectively.

For each initial concentration of sodium thiosulphate (or pyridine) solution, the points lie on a straight line, indicating that the concentration of the expressed solution remains constant over the range of pressures applied. The various lines corresponding to solutions of different initial concentrations cut the axis OX at very nearly the same point (A). This indicates that there is a definite amount of water (represented by OA) associated with the cellulose which does not dissolve any of the sodium thiosulphate (or pyridine) and which is not reduced in quantity by the pressures applied. The distance OA is, therefore, a measure of the water of hydration, i.e., the water which may be regarded as entering into chemical combination with the cellulose.

It should, however, be noted that in the experiments conducted by Champetier, the pressures applied were relatively small and the amount of water associated with the various pressed samples was in all cases considerably greater than that corresponding to saturation vapour pressure. Under these conditions no removal of combined water would be expected to take place. It is at least possible that with pressures sufficiently great to reduce the amount of water associated with the samples to values below that corresponding to saturation vapour pressure, removal of combined water might take place. For example, if the absorption of water by cellulose takes place in the manner suggested by Peirce and represented graphically in Fig. 1, no substantial amount of combined water would be removed at pressures corresponding to water contents of 30 per cent. or more, whereas with pressures sufficiently great to reduce the total moisture below 30 per cent. appreciable amounts of water of hydration would be removed.

The curves representing the composition of the pressed samples would then be straight lines for all moisture contents above the value corresponding to saturation vapour pressure, but for moisture contents below this value the points representing the composition of the pressed samples would lie on a curve passing through the origin.

The pressures applied to the various samples in the present series of experiments were considerably higher than those used in the experiments of Champetier. For example it was possible to reduce the amount of water associated with a pressed sample of bleached cotton yarn to a value as low as 20 gms. per 100 gms. of dry cotton, whereas the lowest figure quoted by Champetier in connection with his experiments on cotton linters correspond to 106 gms. water per 100 gms. dry cotton. In the work now recorded, therefore, the extrapolation necessary to determine the point A (Fig. 4) at which the various lines cut the water axis OX was considerably smaller than in the case of the earlier work by Champetier, but in only one series of experiments, i.e., with cellulose acetate, was it possible to reduce the amount of water associated with the samples below that corresponding to saturation vapour pressure (see Section VI). In this case the curves representing the composition of the pressed samples (Fig. 16) show quite definitely a curvature

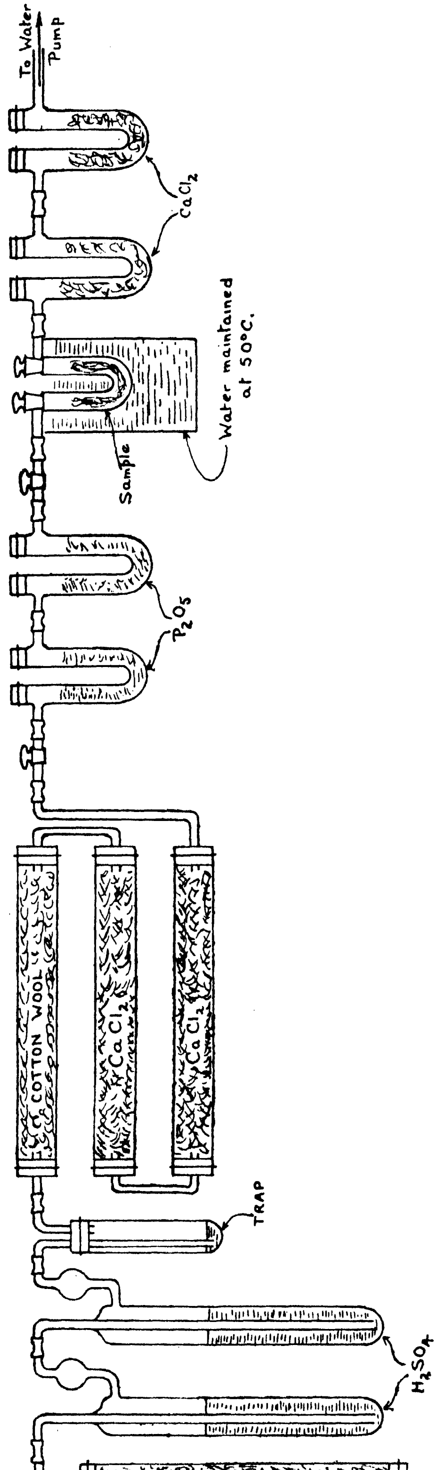

To Water Pump
CaCl2
Water maintained at 50°C.
Sample
P2O5
COTTON WOOL
CaCl2
CaCl2
TRAP
H2SO4
COTTON WOOL

FIG. 5.

towards the origin at the lowest values of moisture content, suggesting that under the highest pressures applied combined water has been removed.

It seems probable therefore that the mechanism of water absorption for cellulose and cellulose compounds is substantially as suggested by Peirce, and that the results of determinations of water of hydration according to the procedure adopted by Champetier indicate the maximum amount of water which can be regarded as entering into chemical combination and do not, as suggested by Champetier, demonstrate the existence of a limited number of definite hydrates.

(b) Experimental Details

The actual details of the procedure adopted in this work vary somewhat according to the type of material under examination. Whenever possible the material was used in the form of yarn. This was wound into small skeins of approximately 0·5 gram each. About 20 samples, each consisting of four or five of the small skeins, were placed in a conditioning chamber over a saturated solution of common salt for several days. The samples were then transferred to weighing bottles and their weights determined. The moisture content, which was assumed to be the same in all the samples, was determined by drawing a stream of dry air over one sample contained in a stoppered U-tube immersed in a bath of water maintained at 50°C. The arrangement of the apparatus is shown in Fig. 5. The sample was completely dried by the above method in about 12 hours.

Five or six of the conditioned samples, suitably marked to facilitiate identification, were placed in an aqueous solution of sodium thiosulphate (120-300 grams $Na_2S_2O_3$ per litre) contained in a stoppered bottle, and allowed to stand at room temperature for several hours (usually about 24 hours), with occasional shaking. After equilibrium was attained, a portion of the solution was withdrawn and the concentration of thiosulphate determined by adding excess of standard iodine solution and back titrating with standard sodium thiosulphate solution.

The samples were then removed one by one from the thiosulphate solution and subjected separately to pressure in a screw press, the pressure applied increasing for successive samples. After pressing, each sample was transferred as quickly as possible to a weighing bottle and weighed. The amounts of sodium thiosulphate in the separate samples were then determined by adding excess N/10 iodine solution and back titrating with N/10 sodium thiosulphate solution using a micro-burette reading to 0·01 c.c. The following quantities could then be determined for each sample:—

Dry weight of sample of yarn = a.
Weight of yarn + thiosulphate solution after pressing = b.
Weight of sodium thiosulphate = c.
Weight of water (by difference) = b − (a + c).

The amounts of water and sodium thiosulphate associated with each of the pressed samples can be expressed as (i) grams of water or thiosulphate per 100 grams of dry yarn, or (ii) molecules of water (H_2O) or thiosulphate ($Na_2S_2O_3$) per molecule of textile material. In the case of cellulose derivatives it is convenient to take the hexose group as the unit of reference.

Further experiments were then made with thiosulphate solutions of different concentrations, using in each case five or six of the conditioned samples.

In the case of cotton, linen, and viscose yarns, the estimation of the thiosulphate associated with any particular sample was carried out in presence

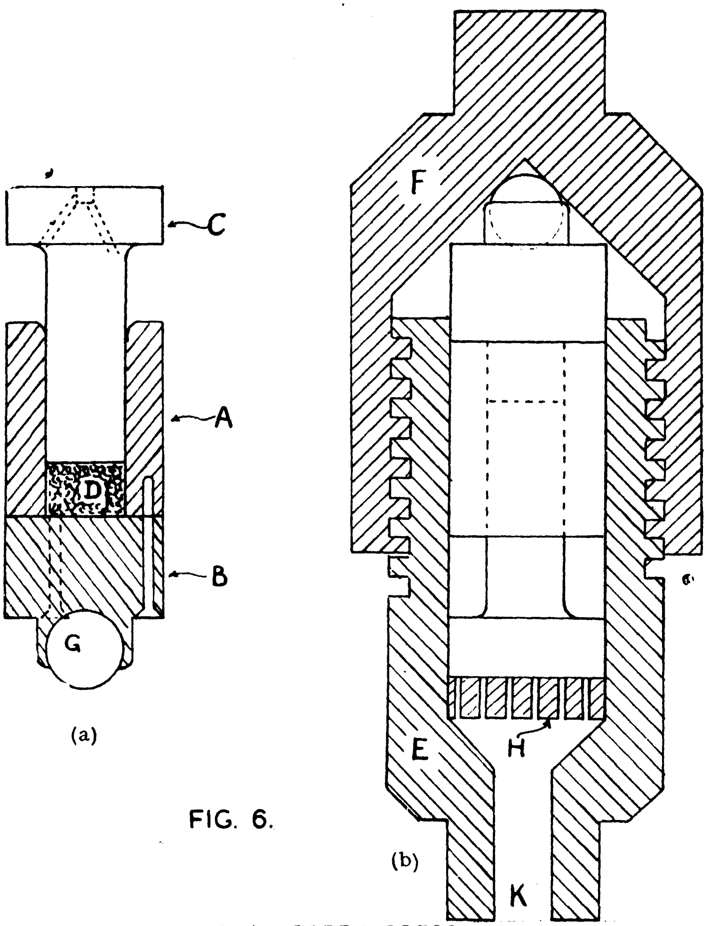
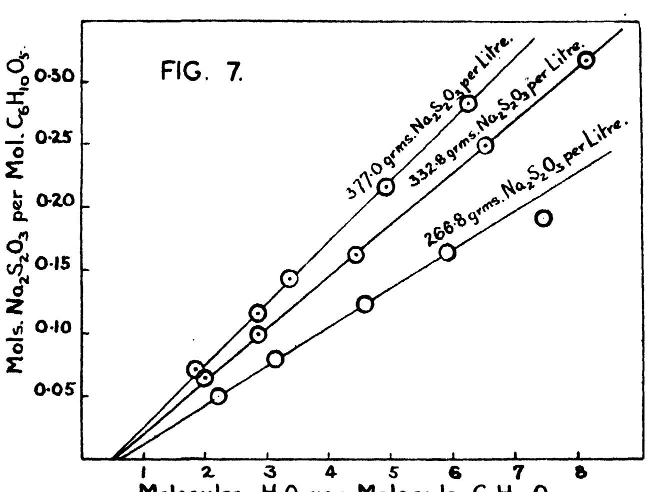


FIG. 6. SCREW PRESS.



COMPOSITION OF PRESSED SAMPLES IMPREGNATED WITH SODIUM THIOSULPHATE SOLUTION

of the yarn. Owing to the fact that cellulose acetate reacts with iodine and is permanently stained thereby (L. Clement, C. Rivière, and A. Beck ; *Chim. et. Ind.*, 1933, **29**, pp.1283-1286), it was necessary in experiments with this material to extract the yarn with hot distilled water, filter, and estimate the thiosulphate in the filtrate.

When the substance under examination could not be obtained in yarn form (e.g., cellulose mono-methylene ether ; hydrocellulose) the following modifications were made in the method of procedure.

12-15 grams of the substance were placed in the thiosulphate solution, and allowed to stand for several hours with occasional shaking. The greater part of the thiosulphate solution was then removed by filtration through a Jena Glass Buchner funnel (11G2), and the wet fibrous mass transferred as quickly as possible to a stoppered bottle. The concentration of thiosulphate in equilibrium with the material under examination was determined by titrating a portion of the filtrate with standard iodine solution. The wet fibrous mass was then divided into five or six portions which were subjected separately to pressure and weighed, as previously described. Each sample was then placed in a Jena Glass filter crucible (1G3) and washed well with hot distilled water. The thiosulphate in the filtrate was estimated, and the crucible containing the washed sample heated at 105°C. in an electrically heated oven until the weight was constant. The dry weight of the sample having been determined, the amount of water associated with the pressed sample could be calculated.

The press used in these experiments is shown in Fig. 6, and consists of a container, shown separately at (a), and the screw press proper, shown at (b).

The container, which is made of cast steel, comprises a hollow cylinder A, having a detachable end-piece B, attached to the cylinder by three screws, and a plunger C, which fits the cylinder A closely. The sample of textile material D, is placed in the cylinder and excess liquor removed by inserting the plunger and applying pressure by hand.

The container is then placed in the screw press as shown at (b). The press consists of two hollow cylinders E and F, made of steel, and having screw threads cut on their outer and inner surfaces respectively. The lower end of E, and the upper end of F, are square in section, thus allowing for the lower cylinder to be held in a vice, whilst torsion is applied to the upper cylinder by means of a suitable double-handled spanner. By this means considerable pressure can be applied to the sample D. To minimise rotation of the cylindical container A, the pressure is transmitted through a ball-bearing G, fitted in the detachable end-piece B. The liquor expelled from the sample under pressure passes through small holes drilled in the base of the plunger C, thence through a perforated steel plate H, to the outlet K. After suitable pressure has been applied to the sample, the upper portion F of the press is unscrewed and the container removed. The end-piece B is removed, and the pressed sample expelled by means of the plunger.

III. THE HYDRATION OF COTTON CELLULOSE

(a) Bleached Cotton Cellulose

The material used in these experiments was 2/80's Combed Egyptian yarn which had been scoured and bleached as follows:—

(i) Washed in several changes of hot water ; rinsed in cold water.

(ii) Steeped 1 hour in 0·3 per cent. HCl solution at room temperature ; washed in cold water.

(iii) Boiled 4 hours in 1 per cent. NaOH + ½ per cent. soap solution ; washed in hot water.
(iv) Steeped ½ hour in ¼° Tw. NaOCl solution at room temperature ; washed in cold water.
(v) Steeped ½ hour in 0·25 per cent. HCl solution at room temperature ; washed in cold water.
(vi) Boiled 4 hours in ½ per cent. soap + ½ per cent. soda ash solution ; washed in hot water.
(vii) Steeped ½ hour in ¼° Tw. NaOCl solution at room temperature ; washed in cold water.
(viii) Steeped ½ hour in 0·25 per cent. HCl solution at room temperature ; washed in cold water ; made alkaline with dilute ammonia ; washed in hot water until neutral, and dried without heat.

The ratio of liquor/yarn in all the above processes was approximately 15/1.

The ternary system cellulose-water-sodium thiosulphate was studied in the manner already described, using the above mentioned yarn. The results are given in Table I, and are shown graphically in Fig. 7. They indicate that the maximum amount of water which can enter into chemical combination with bleached cotton cellulose is 0·5 molecule H_2O per molecule $C_6H_{10}O_5$, corresponding to 5·5 grams of water per 100 grams of dry cotton. This is in good agreement with the result obtained by Champetier using cotton linters.

Table I. Hydration of Cotton Cellulose

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre).	Time of Immersion (Hours).	Composition of Pressed Samples. Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Composition of Pressed Samples. Molecules H_2O per Molecule $C_6H_{10}O_5$	Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
266·8	4	0·1904 0·1646 0·1226 0·0789 0·0516	7·420 5·866 4·548 3·142 2·228	0·53
332·8	4	0·3183 0·2305 0·1632 0·0979 0.0645	8·065 6·491 4·396 2·843 1·991	0·49
377·0	4	0·2798 0.2161 0·1428 0.1153 0·0696	6.212 4·882 3·359 2·811 1·805	0·45
			Mean ...	0·49

Reference has already been made to the mathematical formula developed by Peirce to explain the absorption of water by cellulose. This formula is based upon the assumption that the maximum amount of water which can be associated with the cellulose as in a chemical compound corresponds to one molecule per molecule of cellulose. The results of Champetier, together with those now described, seem to indicate that this assumption is not justified.

(b) Mercerised Cotton Cellulose

2/80's Combed Egyptian yarn, scoured and bleached as described in the previous section was treated with 50° Tw. caustic soda solution (280 grams NaOH per litre) for 10 minutes at room temperature, without tension, washed well in hot water, treated with very dilute acetic acid solution, washed thoroughly in hot water, and dried without heat. This yarn was then used to study the system mercerised cellulose-water-sodium thiosulphate in the manner already described. The results are given in Table II, and are shown graphically in Fig. 8. They indicate that the maximum amount of water which can enter into chemical combination with cellulose mercerised as described above is 0·75 molecule H_2O per molecule $C_6H_{10}O_5$.

Table II. Hydration of Mercerised Cotton Cellulose

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre).	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
		Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Molecules H_2O per Molecule $C_6H_{10}O_5$	
166·1	4	0·1236 0·0883 0·0674 0·0659 0·0409	7·909 5·500 4·356 4·265 3·002	0·83
220·2	4	0·1492 0·1161 0·0897 0·0857 0·0553	7·073 5·302 4·228 4·111 2·943	0·68
281·8	4	0·1924 0·1392 0·1242 0·0827 0·0733	6·415 4·820 4·375 3·182 2·887	0·72
318·8	4	0·1710 0·1521 0·1106 0·0757	5·051 4·550 3·569 2·657	0·75
			Mean ...	0·75

It is well known that when cotton which has been mercerised in caustic soda solution and washed, is dried, a reduction in swelling takes places. On wetting again with water an increase in swelling is produced, but it is not possible to regain the original degree of swelling exhibited by the mercerised cotton before drying. Experiments were therefore made to ascertain whether drying subsequent to mercerisation had any effect on the hydration of cellulose as measured by the method of Champetier. The mercerised yarn used in these experiments was prepared in the manner already described, except that the final drying after mercerisation was omitted. Since it was not possible in these experiments to determine the dry weights of the samples before immersion in the thiosulphate solution, the pressed samples were extracted with hot distilled water, and the thiosulphate estimated in the extract. The samples of yarn were then dried at 105°C. and their weights determined. The results of the experiments are recorded in Table III, and

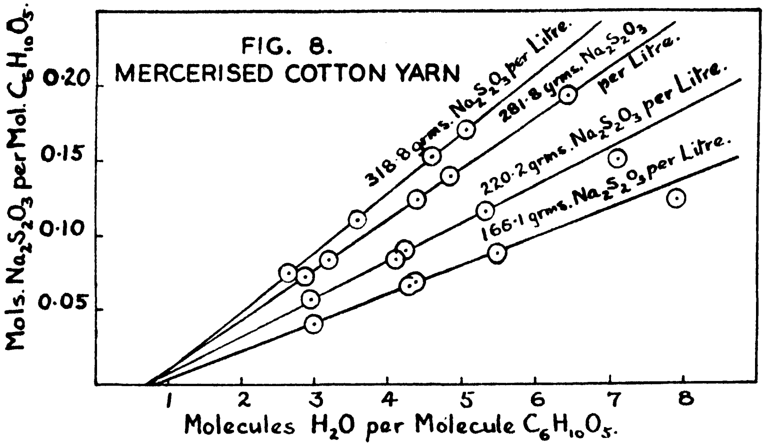


FIG. 8. MERCERISED COTTON YARN

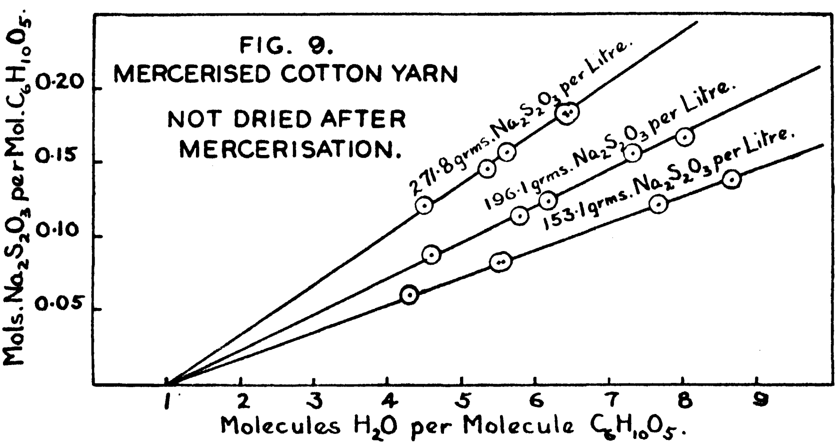


FIG. 9. MERCERISED COTTON YARN

NOT DRIED AFTER MERCERISATION.

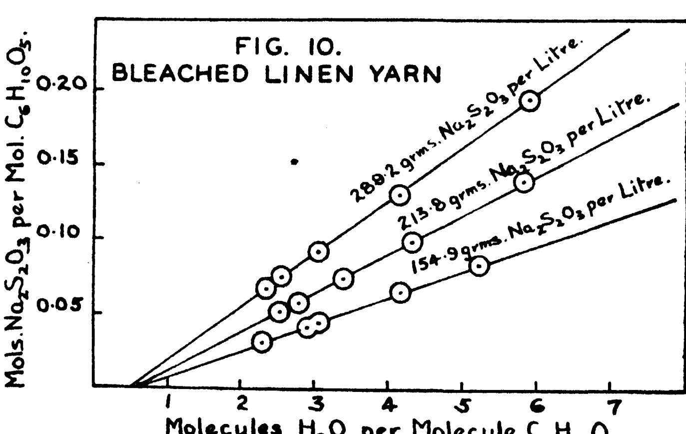


FIG. 10. BLEACHED LINEN YARN

COMPOSITION OF PRESSED SAMPLES IMPREGNATED WITH SODIUM THIOSULPHATE SOLUTION.

Fig. 9, and indicate that the water of hydration of mercerised undried cotton is 1·0 molecule H_2O per molecule $C_6H_{10}O_5$, corresponding to 11·0 grams of water per 100 grams of dry cotton.

Table III. Hydration of Mercerised Cotton Cellulose (not dried after mercerisation)

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
		Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Molecules H_2O per Molecule $C_6H_{10}O_5$	
		0·1379	8·624	
		0·1194	7·650	
153·1	24	0·0808	5·537	0·98
		0·0807	5·498	
		0·0595	4·380	
		0·1643	8·024	
		0·1514	7·341	
196·1	44	0·1221	6·162	0·98
		0·1121	5·799	
		0·0845	4·613	
		0·1845	6·431	
		0· 835	6·455	
271·8	48	0·1813	6·412	1·00
		0·1561	5·611	
		0·1442	5·357	
		0·1205	4·511	
			Mean ...	0·99

IV. THE HYDRATION OF LINEN CELLULOSE

(a) Bleached Linen Cellulose

The material used in these experiments was a brown linen line yarn which was scoured and bleached as follows:—

(i) Washed in several changes of hot water, and rinsed in cold water ;

(ii) Steeped 4 hours in 0·15 per cent. HCl solution at room temperature and washed in cold water ;

(iii) Boiled 1 hour in ½ per cent. NaOH + ½ per cent. soap solution and washed in hot water ;

(iv) Boiled 1 hour in ½ per cent. NaOH + ½ per cent. soap solution and washed in hot water ;

(v) Boiled 2 hours in ½ per cent. soap + ½ per cent. soda ash solution and washed in hot water ;

(vi) Boiled 2 hours in ½ per cent. soap + ½ per cent. soda ash solution and washed in hot water ;

(vii) Steeped 1 hour in ½° Tw. NaOCl solution at room temperature and washed in cold water ;

(viii) Steeped 2 hours in 0·15 per cent. HCl solution at room temperature and washed in cold water ;

(ix) Boiled 4 hours in ½ per cent. NaOH + ½ per cent. soda ash + ½ per cent. soap solution and washed in hot water ;

(x) Steeped 1½ hours in ½° Tw. NaOCl solution at room temperature and washed in cold water ;

(xi) Steeped 1½ hours in ½° Tw. NaOCl solution at room temperature and washed in cold water ;

(xii) Steeped 1 hour in 0·15 per cent. HCl solution at room temperature and washed in cold water ;

(xiii) Boiled 4 hours in ½ per cent. NaOH + ½ per cent. soda ash + ½ per cent. soap solution and washed in hot water ;

(xiv) Steeped 2 hours in ½° Tw. NaOCl solution at room temperature and washed in cold water ;

(xv) Steeped ½ hour in 0·15 per cent. HCl solution at room temperature, washed thoroughly in hot water, and dried without heat.

The results obtained with this material are recorded in Table IV, and Fig. 10. They indicate that the water of hydration of linen cellulose is the same as that of cotton cellulose, i.e., 0·5 molecule H_2O per molecule $C_6H_{10}O_5$.

Table IV. Hydration of Linen Cellulose

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn (Grams /Litre)	Time of Immersion (Hours)	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
		Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Molecules H_2O per Molecule $C_6H_{10}O_5$	
154·9	—	0·0837 0·0645 0·0441 0·0415 0·0308	5·252 4·186 3·065 2·900 2·311	0·57
213·8	98	0·1404 0·0988 0·0734 0·0574 0·0511	5·845 4·351 3·394 2·785 2·530	0·56
289·2	411	0·1946 0·1313 0·0916 0·0744 0·0679	5·896 4·157 3·068 2·549 2·380	0·51
			Mean ...	0·55

(b) Mercerised Linen Cellulose

Scoured and bleached linen yarn as used in the previous experiments was mercerised without tension by treating with 50° Tw. caustic soda solution (280 grams NaOH per Litre) for 10 minutes at room temperature, washing well in hot water, treating with very dilute acetic acid solution, washing thoroughly in hot water, and drying without heat. This yarn was used in the study of the ternary system mercerised cellulose-water-sodium thiosulphate. Experiments were also made using mercerised linen yarn prepared as described above except that the drying after mercerisation was omitted. The results obtained with the yarn which had been dried after mercerisation are given in Table V, and shown graphically in Fig. 11, whilst those obtained with the yarn which had not been dried after mercerisation are recorded in Table VI, and Fig. 12.

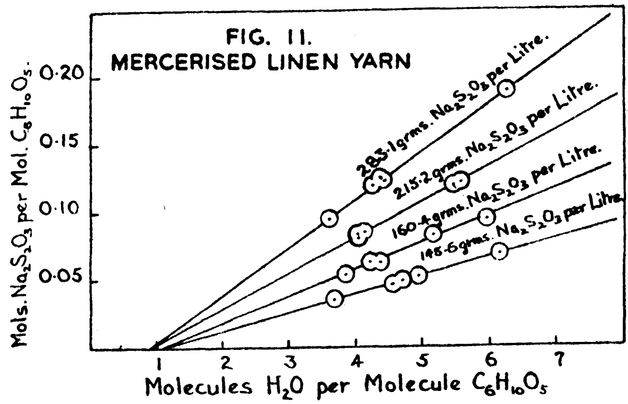
These results indicate that the water of hydration of mercerised linen cellulose corresponds to 1·0 molecule H_2O per molecule $C_6H_{10}O_5$, and that drying subsequent to mercerisation has no effect on the degree of hydration. In this respect linen cellulose shows a marked difference from cotton cellulose.

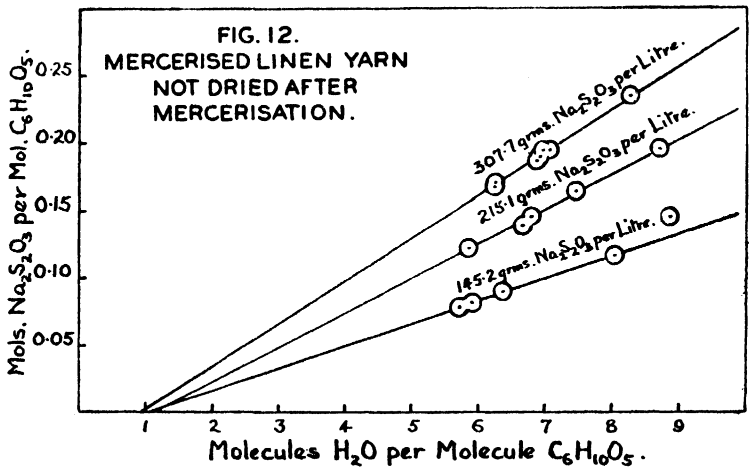
Table V. Hydration of Mercerised Linen Cellulose

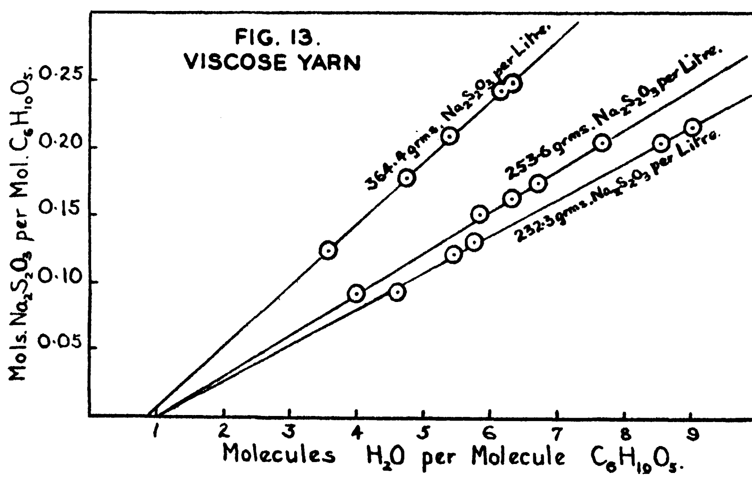
Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples. Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Composition of Pressed Samples. Molecules H_2O per Molecule $C_6H_{10}O_5$	Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
145·6	50	0·0684	6·116	1·17
		0·0518	4·917	
		0·0480	4·660	
		0·0467	4·540	
		0·0341	3·623	
160·4	24	0·0954	5·921	1·15
		0·0821	5·172	
		0·0622	4·338	
		0·0620	4·191	
		0·0533	3·829	
215·2	48	0·1309	5·529	0·98
		0·1191	5·433	
		0·0834	4·103	
		0·0811	3·988	
		0·0801	4·002	
283·1	58	0·1907	6·261	0·90
		0·1240	4·347	
		0·1235	4·393	
		0·1191	4·233	
		0·0949	3·567	
			Mean ...	1·05

Table VI. Hydration of Mercerised Linen Cellulose (not dried after mercerisation)

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples. Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Composition of Pressed Samples. Molecules H_2O per Molecule $C_6H_{10}O_5$	Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
145·2	48	0·1453	8·843	1·07
		0·1165	8·026	
		0·0895	6·340	
		0·0817	5·910	
		0·0778	5·722	
215·1	120	0·1965	8·704	1·15
		0·1644	7·461	
		0·1460	6·778	
		0·1382	6·633	
		0·1216	5·843	
307·7	46	0·2353	8·241	0·92
		0·1953	6·952	
		0·1953	7·065	
		0·1886	6·900	
		0·1869	6·845	
		0·1704	6·229	
		0·1690	6·224	
			Mean ...	1·05







COMPOSITION OF PRESSED SAMPLES IMPREGNATED WITH SODIUM THIOSULPHATE SOLUTION.

V. THE HYDRATION OF REGENERATED CELLULOSE

(a) Viscose Artificial Silk

The material used in these experiments was 100 denier viscose yarn which was scoured for 1 hour at 60°C. in a solution containing 0·5 per cent. olive oil soap + 0·5 per cent. ammonia (·880), the ratio liquor/yarn being 20/1, rinsed well in warm water, and dried without heat. The results obtained are recorded in Table VII, and Fig. 13. They indicate that the water of hydration of regenerated (viscose) cellulose is the same as for mercerised (undried) cellulose, i.e., 1·0 molecule H_2O per molecule $C_6H_{10}O_5$.

Table VII. Hydration of Regenerated (Viscose) Cellulose

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre).	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
		Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Molecules H_2O per Molecule $C_6H_{10}O_5$	
232·3	4	0·2165 0·2041 0·1302 0·1201 0·0931	9·028 8·541 5·753 5·455 4·591	1·05
253·6	4	0·2047 0·1738 0·1627 0·1510 0·0917	7·678 6·676 6·310 5·842 3·999	1·00
364·4	4	0·2473 0·2427 0·2084 0·1776 0·1239	6·311 6·153 5·363 4·767 3·558	0·85
			Mean ...	0·97

Table VIII. Hydration of Mercerised Regenerated (Viscose) Cellulose

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
		Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Molecules H_2O per Molecule $C_6H_{10}O_5$	
146·7	4	0·1574 0·1002 0·0842 0·0715 0·0488	10·38 7·109 5·953 5·518 4·127	1·29
223·5	4	0·2023 0·1351 0·1298 0·1189 0·0840	8·549 6·181 5·944 5·499 4·266	1·18
295·4	4	0·2998 0·2173 0·1927 0·1459 0·1117	9·243 7·148 6·241 5·035 4·090	1·04
			Mean ...	1·17

(b) Mercerised Viscose Artificial Silk

The scoured yarn as used in Section (a) above, was treated with 50° Tw. caustic potash solution (327·5 grams KOH per litre) for 1 minute at room temperature, washed well in water, treated with very dilute acetic acid solution, washed well, and air dried. The results are recorded in Table VIII, and Fig. 14. Although the actual values recorded in Table VIII indicate a slight increase in the amount of water of hydration as a result of mercerisation, the graphical representation (Fig. 14) suggests that the value 1 molecule H_2O per molecule $C_6H_{10}O_5$ is probably correct for both the mercerised and unmercerised viscose yarn.

(c) Lilienfeld Viscose Artificial Silk

Ordinary viscose yarn shows a considerable decrease in tensile strength on wetting with water, but Lilienfeld has patented a process for the preparation of viscose in which, instead of the usual precipating bath of dilute acid, a bath of strong acid (not less than 40 per cent. by weight) is used. This results in the production of a yarn which differs markedly from ordinary viscose in several respects. One of the most important of these is that it does not suffer any appreciable reduction in tensile strength on wetting with water. It seemed possible that this characteristic might be due to some difference in the amount of water of hydration. Experiments were, therefore, made with a 160 denier Lilienfeld yarn which had been scoured in a solution of soap and ammonia as described in Section (a) above. The results obtained are recorded in Table IX, and Fig. 15, and show that the amount of water of hydration corresponds approximately to 1·0 molecule H_2O per molecule $C_6H_{10}O_5$, as in the case of ordinary viscose.

Table IX. Hydration of Regenerated Cellulose (Lilienfeld Viscose)

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre).	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
		Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Molecules H_2O per Molecule $C_6H_{10}O_5$	
184·9	4	0·1270 0·1056 0·0881 0·0758 0·0541	7·078 6·013 5·364 4·703 3·698	1·15
257·2	4	0·1734 0·1241 0·1126 0·1092 0·0754	6·747 5·136 4·735 4·505 3·585	1·04
302·5	4	0·2595 0·2141 0·1858 0·1415 0·1265	8·098 6·808 6·063 4·906 4·515	1·10
			Mean ...	1·10

VI—THE HYDRATION OF CELLULOSE ACETATE

The material used in these experiments was 140 denier Celanese yarn which had been scoured for 1 hour at 60° C. in a solution containing 0·5 per cent. olive oil soap + 0·5 per cent. ammonia (·880), washed well in warm water, and dried without heat. The results are given in Table X, and Fig.

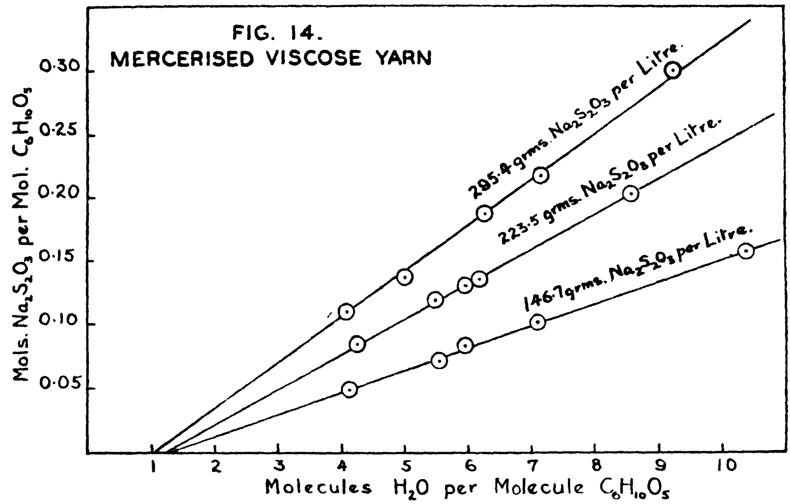


FIG. 14.
MERCERISED VISCOSE YARN

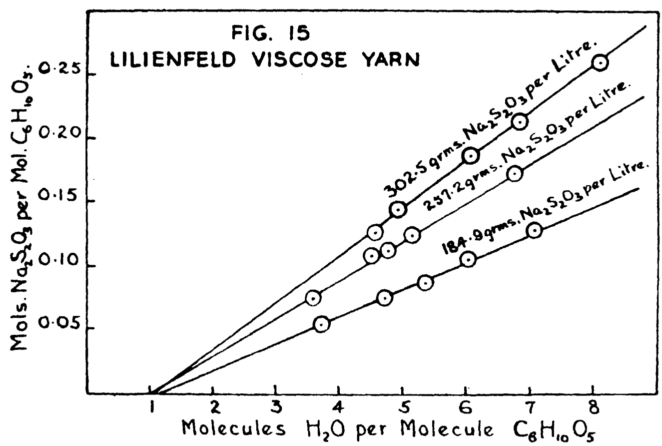


FIG. 15
LILIENFELD VISCOSE YARN

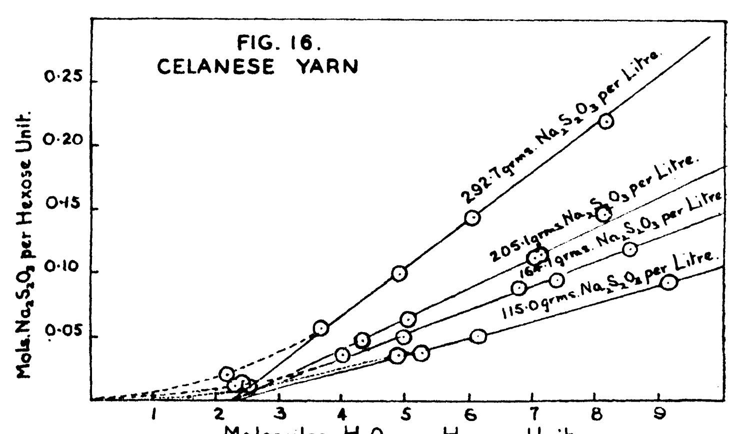


FIG. 16.
CELANESE YARN

COMPOSITION OF PRESSED SAMPLES IMPREGNATED WITH SODIUM THIOSULPHATE SOLUTION.

16. In order to express the amounts of sodium thiosulphate and water associated with the pressed samples as molecules $Na_2S_2O_3$ and H_2O per hexose unit, it was necessary to calculate a value for the " molecular weight " of the cellulose acetate. The acetic acid content of the cellulose acetate was therefore determined as follows:

About 2 grams of the yarn was dried and its weight determined. It was then allowed to stand for several hours in a mixture of equal volumes of acetone and water. The swollen yarn was rinsed in water, placed in a conical flask, and a known volume of N/1 sodium hydroxide solution added. After warming the contents to about 50° C. the flask was allowed to stand for 1 hour, shaking at frequent intervals. The excess alkali was then estimated by titration with N/5 hydrochloric acid, using phenol phthalein as indicator. From the amount of caustic soda used up the acetic acid content of the cellulose could be calculated.

Knowing the acetic acid content, a value could be calculated for the " molecular weight " of the cellulose acetate, from the fact that it is formed by the combination of acetic acid and cellulose, one molecule of water being eliminated for every molecule of acetic acid combined.

Table X. Hydration of Cellulose Acetate (51·5 per cent. CH_3COOH)

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Hexose unit
		Molecules $Na_2S_2O_3$ per Hexose unit	Molecules H_2O per Hexose unit	
115·0	24	0·0923 0·0516 0·0380 0·0340 0·0100	9·080 6·113 5·259 4·849 2·468	2·36
164·1	24	0·1188 0·0965 0·0871 0·0509 0·0341 0·0132 0·0121 0·0098	8·502 7·352 6·759 4·957 4·054 2·415 2·404 2·290	2·28
205·1	48	0·1440 0·1161 0·1129 0·0640 0·0477	8·069 7·098 6·976 5·020 4·284	2.35
292·7	24	0·2201 0·1435 0·0984 0·0578 0·0199	8·085 6·024 4·850 3·663 2·182	2·23
			Mean ...	2·30

It will be noticed from Fig. 16, that the points representing the amounts of water and sodium thiosulphate associated with the various series of pressed samples do not lie on straight lines, but give curves which tend towards the origin (dotted lines). The method of determination of water of hydration adopted in this work depends upon the assumption that the application of pressure to the samples only removes that portion of the absorbed water which

is held in a loose manner by physical forces operating at the surface of the material, and does not affect the water of hydration itself. It is obvious, therefore, that if the amounts of water in the two phases can be represented by curves similar to those shown in Fig. 1, some of the water of hydration will be removed if the pressure is sufficiently great. For example, according to Fig. 1, an appreciable amount of water of hydration would be removed if the pressure were sufficiently great to reduce the total moisture in the sample below 30 per cent. It will be noticed from Table X, that in the case of Celanese yarn it has been possible to reduce the amount of water associated with the samples to a value as low as 16 per cent. It seems probable, therefore, that with these high pressures, water of hydration has been removed from the samples. At lower pressures, however, corresponding to water contents of 30 per cent. or over, it seems reasonable to suppose that no substantial amounts of water of hydration have been removed, since the points corresponding to these determinations lie on straight lines. These straight lines have, therefore, been produced, and they cut the water axis at substantially the same point. This has been taken as the correct value for the water of hydration. This value is 2·30 molecules H_2O per hexose unit corresponding to 16·4 grams of water per 100 grams of dry Celanese yarn. The acetic acid content of the yarn was 51·5 per cent. corresponding to 2·17 molecules CH_3COOH per hexose unit.

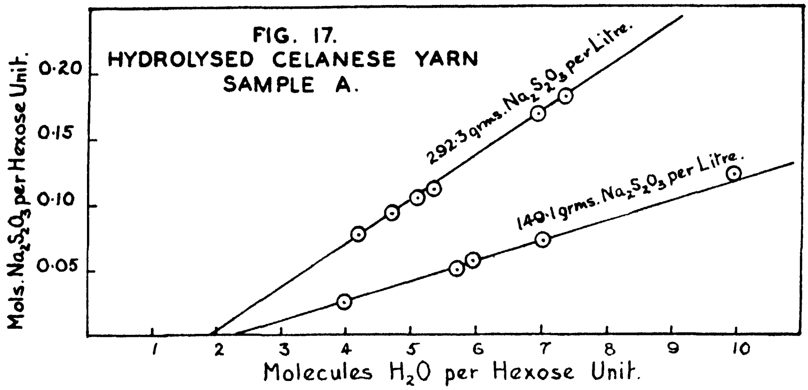
It has been suggested that only one acetate of cellulose actually exists, i.e., the triacetate $C_6H_7O_2(O{\cdot}COCH_3)_3$, and that what have been regarded as mono- or di-acetates or mixtures of the three acetates are in fact mixtures of the tri-acetate with cellulose (Dorée, "Methods of Cellulose Chemistry" (Chapman and Hall), p.258). If this suggestion is correct, it will affect the determination of water of hydration, since the total amount of water of hydration in a sample of cellulose acetate will consist of

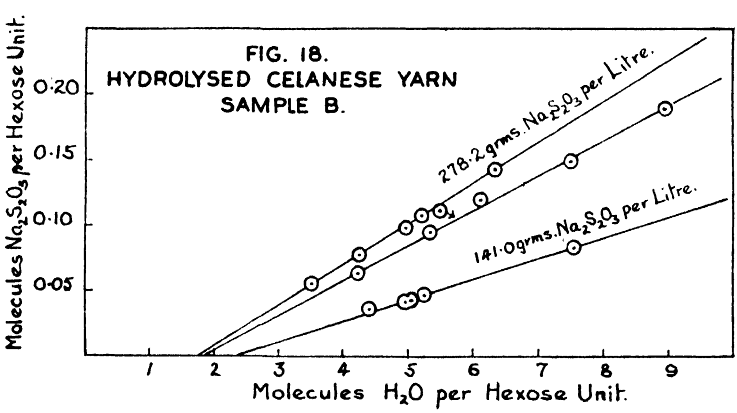
(a) that which is combined with the cellulose itself ; this might possibly correspond to any of the values already determined for cellulose, viz., 0·5, 0·75, or 1·0 molecule H_2O per molecule $C_6H_{10}O_5$; and

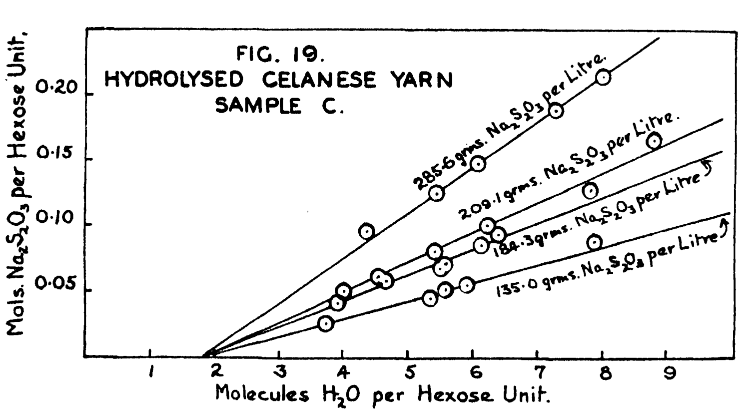
(b) that which is combined with the cellulose triacetate ; from the results obtained with Celanese yarn, it is obvious that this will be much greater than that of the cellulose.

The amount of water of hydration of cellulose triacetate has been calculated from the data obtained for Celanese yarn, assuming that it consists of a mixture of 82·4 per cent. cellulose triacetate and 17·6 per cent. cellulose, and that the water of hydration of the cellulose is 0·5 molecule H_2O per molecule $C_6H_{10}O_5$. The result obtained is 3·0 molecules H_2O per molecule $C_6H_7O_2(O.COCH_3)_3$.

This result is of particular interest in view of the generally accepted theory that the hydroxyl groups of the cellulose molecule are the chief points of attachment for water molecules. The fact that a compound such as cellulose acetate absorbs less moisture than cellulose itself in an atmosphere of any given humidity, is generally regarded as being due to the fact that the acetylation has caused a reduction in the number of hydroxyl groups (Urquhart, *J. Text. Inst.*, 1929, **20**, T125). The alteration in the number of hydroxyl groups in the cellulose molecule, however, would presumably affect only that portion of the absorbed water which can be regarded as entering into chemical combination with the cellulose molecule, i.e., the water of hydration measured in the experiments now described. The results obtained with







COMPOSITION OF PRESSED SAMPLES IMPREGNATED WITH SODIUM THIOSULPHATE SOLUTION.

Celanese yarn, however, indicate that the replacement of some of the hydroxyl groups of the cellulose molecule by acetyl groups does not reduce the amount of water of hydration, but actually makes it possible for a much greater amount of water to enter into chemical combination with the textile material.

It seemed desirable, in view of the results obtained with the Celanese yarn, to carry out similar experiments on samples of cellulose acetate of different acetic acid contents, to see whether any confirmation could be obtained of the theory that the only acetate of cellulose which actually exists is the triacetate. Such samples were obtained by submitting samples of Celanese yarn to partial hydrolysis. This hydrolysis was carried out by treating the scoured yarn for a suitable time with a dilute solution of caustic soda at 20° C. After this treatment the yarn was plunged into a large bulk of cold water to stop the reaction, washed free from alkali, and dried without heat. The details of the treatments and the results of the determinations of the acetic acid contents of a number of samples prepared in this manner are given in Table XI.

Table XI. Hydrolysis of Celanese Yarn

Sample	Treatment		Acetic Acid Content (Grms. CH_3COOH per 100 Grms. Yarn)
	Conc. of NaOH	Time (Hours)	
A	0·2 N.	1	28·36
B	0·2 N.	2	24·44
C	0·2 N.	5	21·58
D	0·4 N.	4	6·82

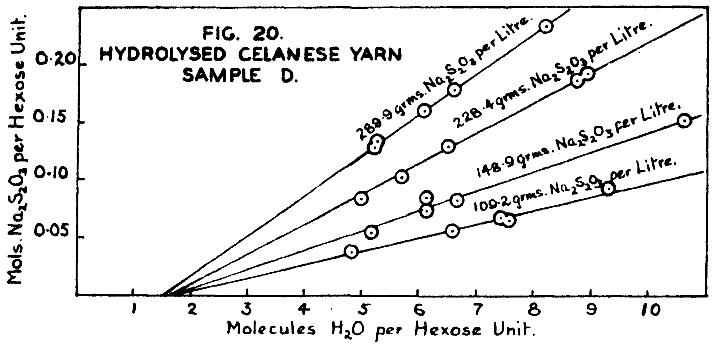
The results of determinations of water of hydration on these samples are recorded in Tables XII, XIII, XIV, and XV, and also in Figs. 17, 18, 19, and 20.

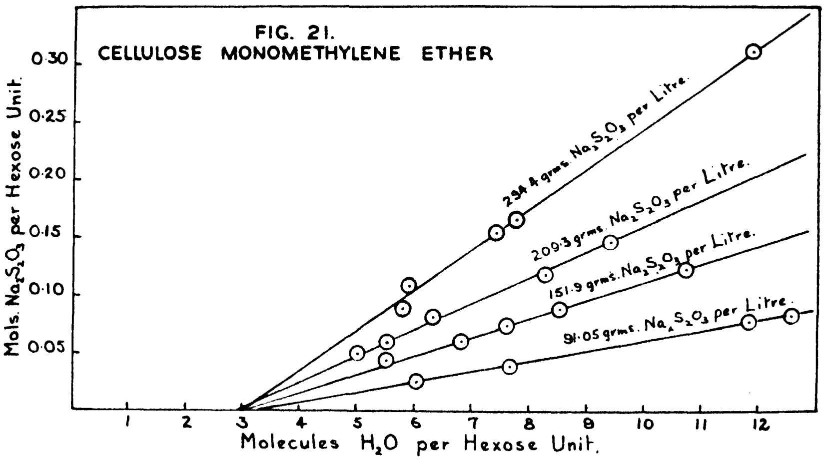
The amount of water of hydration of cellulose acetate is compared with the acetic acid content in Table XVI.

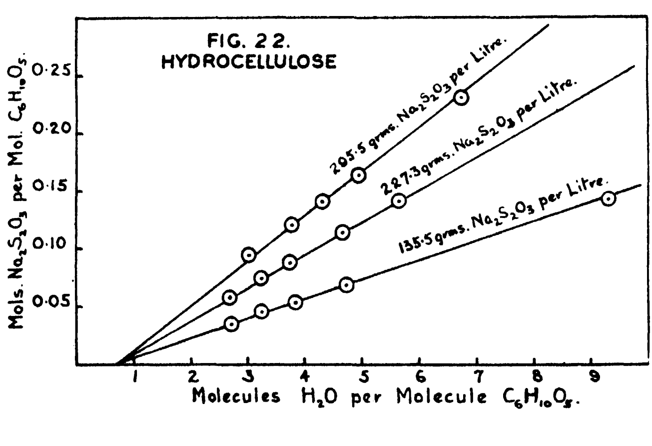
Although the amount of water of hydration (expressed as molecules H_2O per hexose unit) decreases as the acetic acid content is lowered, there does not seem to be any direct relationship between the two quantities. The experiments on hydrolysed Celanese yarn, therefore, do not support the idea that cellulose acetate consists of a mixture of cellulose tri-acetate and cellulose.

Table XII. Hydration of Cellulose Acetate (28·36 per cent. CH_3COOH) (Hydrolysed Sample A)

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Hexose unit
		Molecules $Na_2S_2O_3$ per Hexose unit	Molecules H_2O per Hexose unit	
149·1	26	0·1225 0·0726 0·0562 0·0503 0·0261	9·815 7·015 5·948 5·703 3·977	2·13
292·3	72	0·1828 0·1689 0·1113 0·1068 0·0926 0·0784	7·348 6·956 5·343 5·101 4·713 4·209	1·95
			Mean ...	2·04







COMPOSITION OF PRESSED SAMPLES IMPREGNATED WITH SODIUM THIOSULPHATE SOLUTION.

Table XIII. Hydration of Cellulose Acetate (24·44 per cent. CH_3COOH) (Hydrolysed Sample B)

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples. Molecules $Na_2S_2O_3$ per Hexose unit	Composition of Pressed Samples. Molecules H_2O per Hexose unit	Water of Hydration Molecules H_2O per Hexose unit
141·0	144	0·0820 0·0466 0·0424 0·0410 0·0342	7·548 5·248 5·048 4·960 4·412	2·34
—	124	0·1875 0·1480 0·1197 0·1113 0·0941 0·0626	8·945 7·501 6·095 5·512 5·314 4·228	1·82
278·2	72	0·1421 0·1036 0·0979 0·0770 0·0551	6·324 5·177 4·966 4·233 3·494	1·77
			Mean ...	1·98

Table XIV. Hydration of Cellulose Acetate (21·58 per cent. CH_3COOH) (Hydrolysed Sample C)

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples. Molecules $Na_2S_2O_3$ per Hexose unit	Composition of Pressed Samples. Molecules H_2O per Hexose unit	Water of Hydration Molecules H_2O per Hexose unit
135·0	50	0·0871 0·0571 0·0511 0·0463 0·0257	7·854 5·907 5·554 5·325 3·702	1·82
184·3	28	0·1284 0·0931 0·0861 0·0711 0·0679 0·0577 0·0419	7·812 6·339 6·092 5·304 5·254 4·624 3·870	1·86
209·1	19	0·1668 0·1006 0·0809 0·0612 0·0497	8·760 6·216 5·384 4·529 4·012	1·86
285·6	168	0·2151 0·1882 0·1483 0·1241 0·0944	7·986 7·213 6·068 5·391 4·333	1·82
			Mean ...	1·84

Table XV. Hydration of Cellulose Acetate (6·82 per cent. CH_3COOH) (Hydrolysed Sample D)

Concentration of $Na_2S_2O_3$ in Equilibrium with Yarn. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Hexose unit
		Molecules $Na_2S_2O_3$ per Hexose unit	Molecules H_2O per Hexose unit	
109·2	27	0·0925 0·0686 0·0648 0·0555 0·0370	9·303 7·422 7·558 6·616 4·811	1·68
148·9	24	0·1523 0·0829 0·0823 0·0731 0·0554	10·62 6·108 6·655 6·094 5·136	1·59
228·4	26	0·1929 0·1857 0·1285 0·1031 0·0837	8·902 8·724 6·491 5·667 4·969	1·66
289·9	50	0·2336 0·1778 0·1605 0·1303 0·1276	8·153 6·618 6·066 5·231 5·216	1·59
			Mean ...	1·63

Table XVI. Water of Hydration of Cellulose Acetate

Acetic Acid Content Mols. CH_3COOH per Hexose Unit.	Water of Hydration Mols. H_2O per Hexose Unit.
2·17	2·30
0·96	2·04
0·80	1·98
0·68	1·84
0·19	1·63

VII. THE HYDRATION OF CELLULOSE MONO-METHYLENE ETHER.

The material used in these experiments was prepared by F. C. Wood, according to the method elaborated by him (*J. Soc. Chem. Ind.*, 1931, **50**, 411T). It contains 17·2 per cent. of methylene oxide, corresponding to the formula $C_6H_7O_2$ $(OH)(O_2CH_2)$, and is fibrous in structure. The fibres, however, are of very short length (about 1/200 inch). The results of the experiments made with this material are given in Table XVII, and Fig. 21, and indicate a very high value for the water of hydration of the cellulose ether, viz., 3·0 molecules H_2O per molecule $C_6H_7O_2(OH)(O_2CH_2)$.

This result, like that obtained with cellulose acetate is of particular interest, in view of the generally accepted theory that the hydroxyl groups of the cellulose molecule are the chief points of attachment for water molecules. The replacement of two of the three hydroxyl groups in the cellulose molecule by methylene groups has not reduced the amount of water of hydration, but has made it possible for a much greater amount of water to enter into chemical combination with the cellulose derivative.

Table XVII. Hydration of Cellulose Mono-methylene Ether.

Concentration of $Na_2S_2O_3$ in Equilibrium with Fibre. (Grams/Litre)	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Hexose unit
		Molecules $Na_2S_2O_3$ per Hexose unit	Molecules H_2O per Hexose unit	
91·0	48	0·0848	12·59	3·40
		0·0785	11·79	
		0·0389	7·647	
		0·0254	6·078	
151·9	123	0·1232	10·70	3·00
		0·0873	8·513	
		0·0734	7·615	
		0·0627	6·834	
		0·0390	5·517	
209·3	120	0·1467	9·414	2·75
		0·1178	8·249	
		0·0812	6·305	
		0·0601	5·496	
		0·0508	5·010	
294·4	24	0·3113	11·84	2·97
		0·1666	7·727	
		0·1554	7·398	
		0·1086	5·882	
		0·0921	5·782	
			Mean ...	3·03

VIII. THE HYDRATION OF HYDROCELLULOSE

The material used in these experiments was a degraded cellulose prepared by treating 2/80's scoured and bleached Egyptian yarn for two periods of 4½ hours each in approximately N/1 hydrochloric acid solution at 70° C., washing well in hot water, and drying without heat. About 34 grams of the product, which was in the form of very short fibres, was obtained from 40 grams of the original cotton yarn. The results of the experiments made with this material are given in Table XVIII, and Fig. 22. They indicate that the amount of water of hydration corresponds to 0.67 molecule H_2O per molecule $C_6H_{10}O_5$, assuming that the material consisted entirely of hydrocellulose, and that the formula for hydrocellulose is the same as that of cellulose itself (Dorée, " Methods of Cellulose Chemistry " (Chapman and Hall), p.148).

It seemed probable, however, that the material used in these experiments consisted of a mixture of hydrocellulose and cellulose, and an estimation of its composition was, therefore, made, based upon the well-known fact that whereas cellulose itself is practically insoluble in sodium hydroxide solution, hydrocellulose dissolves readily in this reagent. A determination was made of the " Solubility Number " of the material, according to the method of Birtwell, Clibbens, and Geake (*J. Text. Inst.*, 1928, **19**, T349). The result showed that under the particular conditions employed in this determination, 72.2 per cent. by weight of the material dissolved in sodium hydroxide solution. It seemed reasonable, therefore, to assume that the material used in these experiments consisted of a mixture of 72.2 per cent. hydrocellulose and 27.8 per cent. ordinary cellulose. The amount of water of hydration of hydrocellulose was calculated upon this assumption, the value for the unchanged cellulose being taken as 0.5 molecule H_2O per molecule $C_6H_{10}O_5$. The result obtained was 0.73 molecule H_2O per molecule $C_6H_{10}O_5$.

Table XVIII. Hydration of Hydrocellulose

Concentration of $Na_2S_2O_3$ in Equilibrium with Fibre. (Grams/Litre).	Time of Immersion (Hours).	Composition of Pressed Samples.		Water of Hydration Molecules H_2O per Molecule $C_6H_{10}O_5$
		Molecules $Na_2S_2O_3$ per Molecule $C_6H_{10}O_5$	Molecules H_2O per Molecule $C_6H_{10}O_5$	
135·5	24	0·1427 0·0679 0·0541 0·0452 0·0345	9·281 4·733 3·828 3·359 2·675	0·65
227·3	50	0·1402 0·1141 0·0879 0·0745 0·0579	5·631 4·667 3·768 3·263 2·667	0·67
295·5	94	0·2303 0·1634 0·1396 0·1204 0·0934	6·751 4·923 4·305 3·788 3·033	0·68
			Mean ...	0·67

IX. SUMMARY

The various theories which have been advanced to explain the phenomena associated with the absorption of water by cellulose and cellulose compounds are reviewed and some reference is made to the experimental work upon which these theories are based. The method of Champetier for the determination of water of hydration is discussed in detail and his method has been applied to the study of the absorption of water by cellulose and a number of cellulose compounds.

It is suggested that the results of these experiments do not indicate that cellulose and its compounds form a limited number of definite hydrates, but that there is, for each of the substances examined, a maximum amount of water which can be regarded as entering into chemical combination.

This maximum value corresponds to 0·5 molecule H_2O per molecule $C_6H_{10}O_5$ in the case of bleached cotton and linen cellulose ; 0·75 molecule H_2O per molecule $C_6H_{10}O_5$ for mercerised cotton cellulose which has been dried subsequent to mercerisation ; and 1·0 molecule H_2O per molecule $C_6H_{10}O_5$ for mercerised cotton cellulose which has not been dried after mercerisation, for mercerised linen cellulose whether dried or not after mercerisation, and for regenerated (viscose) cellulose. The results obtained with cellulose acetate suggest a value of 3·0 molecules H_2O per hexose unit for cellulose tri-acetate, and a similar value is obtained with cellulose monomethylene ether.

X. ACKNOWLEDGMENTS

My thanks are due to Dr. F. C. Wood who called my attention to the work of Champetier on cotton cellulose, and suggested that a similar technique should be employed to study the absorption of water by linen cellulose ; also for supplying a quantity of cellulose methylene ether, and for the great interest he has shown in the work.

The screw press (Fig. 6b) was kindly lent by Mr. H. J. P. Venn, who had previously used it for work of a different character.

The experiments described in this paper were carried out in the Research department of Messrs. Tootal Broadhurst Lee Co. Ltd., 56, Oxford Street, Manchester, to whom my thanks are due for permission to publish this account.

Received 3/5/37

19—A PHOTOMETER FOR THE MEASUREMENT OF THE LUSTRE OR GLOSS OF TEXTILE AND OTHER MATERIALS. PART 1. CONSTRUCTION OF INSTRUMENT.

By D. A. Derrett-Smith.
(Linen Industry Research Association).

Instruments which have been designed for studying the lustre or gloss of textile materials may be considered in two classes :—

1. Those in which the illuminating beam is inclined at a fixed angle to the plane of the fabric or other material under test, the lustre being expressed as the ratio of the intensities of the reflected light at the specular angle and at some other fixed angle.

2. Instruments in which the lustre is computed from observations made on the intensity of the light reflected from the fabric at a number of angles for different angles of incidence of the illuminating beam.

Among instruments in the first class may be mentioned :—

The Goerz Glarimeter,[1] in which a beam of light is incident on the test surface at 60° and the ratio of the intensity of the light reflected at 60° (the specular angle) to that at another arbitrary angle (30°) is obtained as a single figure by means of a calibrated grey wedge which allows the intensity of the light reflected at the specular angle to be matched against that reflected at the diffuse angle.

The Comparative Gloss Meter (*Salford Electrical Instruments, Ltd.*). In this case, a beam of light illuminates the sample at 45° and the reflected light is measured at 45° and at 0° by means of a movable photo-electric cell which is placed first in the 45° position and then in the 0° position.

The modified form of the Toussaint Photo-electric Photo-colorimeter described by Desbleds[2]. Measurements are made in two positions of the sample by means of a photo-electric cell.

The Ingersoll Glarimeter[3] also falls logically into this class but differs from the other instruments in that the beam of light falls on the test surface at the angle (57·5°) at which the light reflected in the specular direction is most completely polarised and the lustre is then expressed as the proportion of this reflected light which is polarised.*

It has been shown that the figures given by the instruments in this class are insufficient to specify the lustre in the case of structured materials such as textile fabrics.

The following instruments may be mentioned as falling into the second class :—

Schulz and Ewald[6] described an instrument in which the observing and the illuminating parts are both adjustable, and observations may be made at a number of angles and for different angles of incidence of the illuminating beam. Comparison is made between the intensities of the light reflected from the test surface at an interval of 15° by means of a grey wedge and a number of calibrated neutral filters.

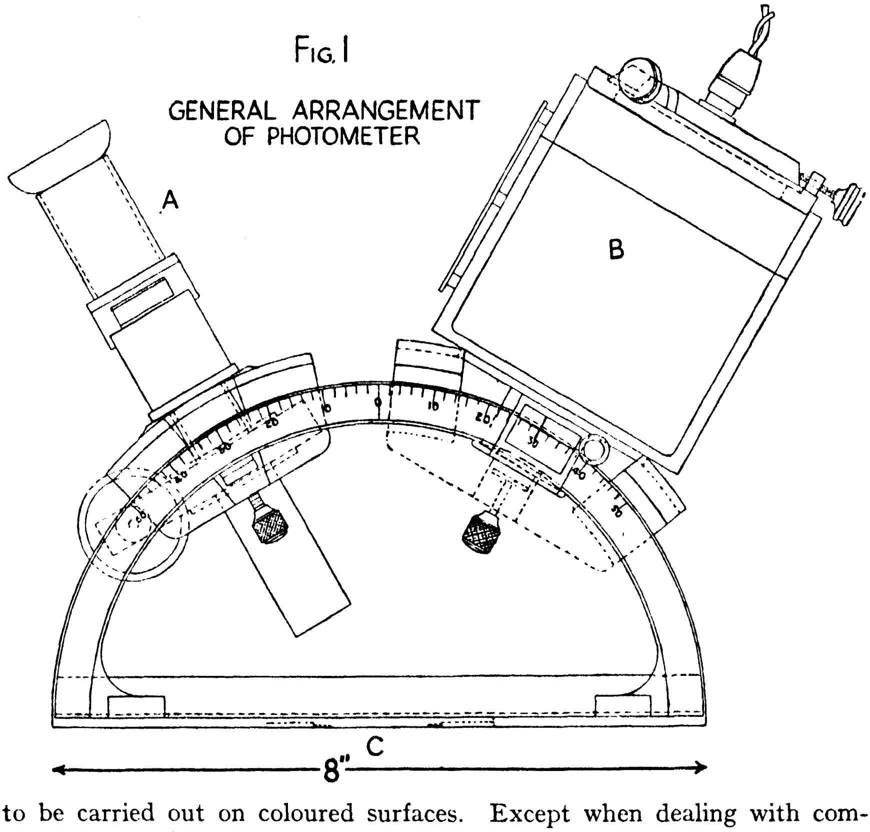
Pulfrich[7] described a photometer which is adapted for the measurement of the lustre as well as of a number of other properties of textile materials. The sample to be measured is placed in a special holder side by side with a

*The use of the material " Polaroid "[4,5] has been proposed for measuring lustre in a similar manner. This material consists of a cellulosic or other film cemented between plates of glass and containing a substance capable of polarising light passing through it.

standard white plate of barium sulphate. The sample and the standard are illuminated by two approximately parallel beams of light from the same source and the brightness of the test surface is measured by means of a comparison photometer in terms of that of the standard for a number of positions, both sample and standard being tilted simultaneously towards the illuminating beams. In this way a curve can be obtained connecting relative brightness with angle of tilt. The angle of incidence is fixed arbitrarily at 45° and observations are made with the photometer in the vertical position. Arrangements are provided whereby the sample may be rotated in its own plane and observations made, for example, in the warp and weft directions of a fabric. A set of colour filters enables measurements

FIG. I

GENERAL ARRANGEMENT OF PHOTOMETER



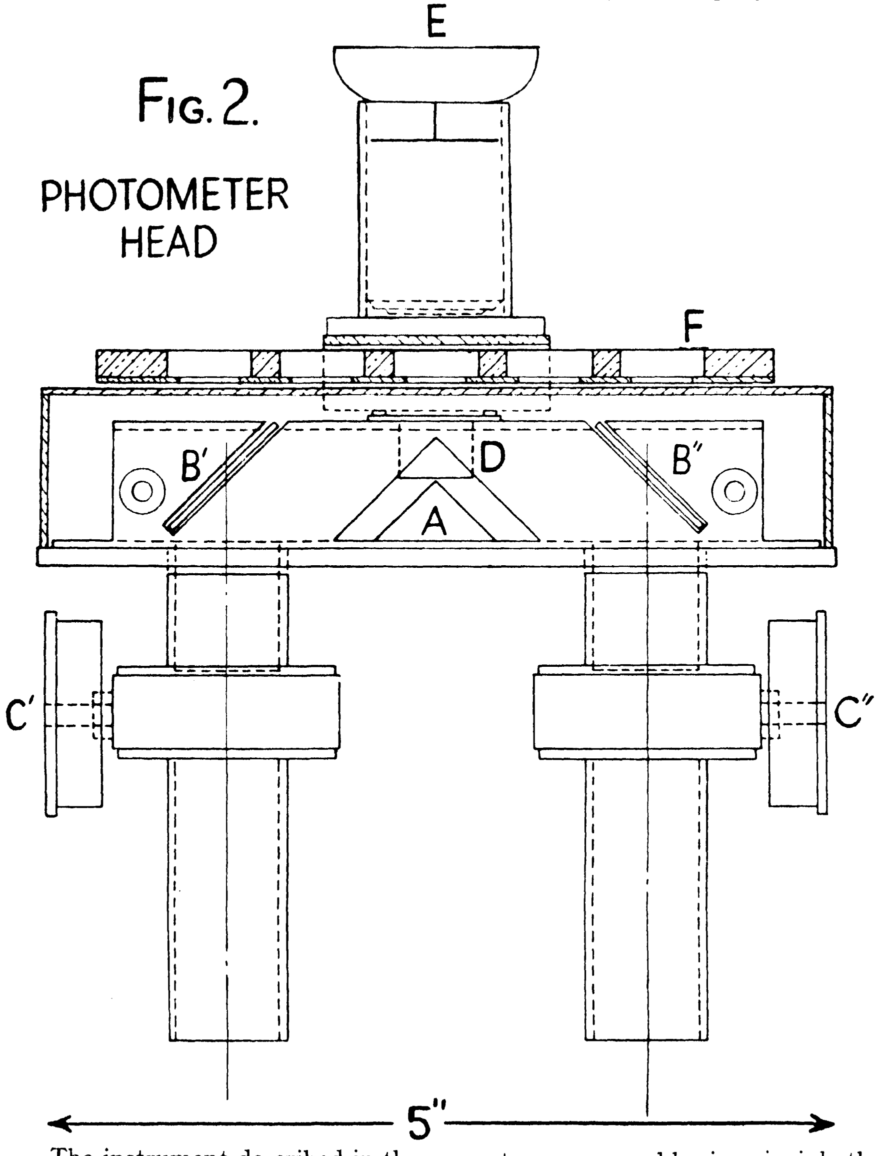
to be carried out on coloured surfaces. Except when dealing with comparatively small pieces of fabric it is necessary in using this apparatus to cut out a sample for placing in the holder.

Boffey and Derrett-Smith[8] described a photometer in which the observing and illuminating parts were movable through a range of angles. A portion of the fabric being measured was observed, without cutting, through an aperture in the base-plate. In this instrument a Wanner polarisation photometer head (as used in pyrometry) was employed and the brightness of the surface was compared at a number of angles with that of a standard lamp running at a constant current. Difficulties connected with the constancy and colour of the illumination led to modifications in the method of determining the brightness of the test surface.

In considering the application of the photo-electric cell for the purpose, it was concluded that, while it appears to offer advantages regarding the obviation of personal errors in measurement, it possesses disadvantages which make it preferable to use a method where the intensities of two sources are compared by variable apertures. The eye is capable of measuring by this means to within 1-2 per cent., which is sufficient for practical purposes.

FIG. 2.

PHOTOMETER HEAD



The instrument described in the present paper resembles in principle the photometer described by Pulfrich but differs from it in several important ways. Both the observing and the illuminating parts are movable. The instrument is compact and portable and may be placed on a piece of cloth or other material to be measured without the necessity of cutting a sample, since the latter remains always in the horizontal position.

It is proposed in this paper (Part I) to describe the construction of the instrument and in a subsequent communication to consider some results obtained with it.

The Construction of the Instrument.

The general arrangement is shown diagrammatically in Figure 1. The instrument consists essentially of a comparison photometer (A) provided with two variable apertures and mounted on semi-circular travel-bars which enable it to be moved through a range of angles. Also on the travel-bars is mounted an illuminating arrangement (B) by means of which the standard white plate of barium sulphate and the material to be measured are illuminated by two approximately parallel beams derived from a common source. This illuminating arrangement is also capable of being moved through a range of angles. At any given angle, the two optical axes of the photometer and those of the two illuminating beams pass respectively through the centres of slots in the base-plate (C). Through one of the photometer apertures is viewed the standard white plate accommodated in one of these slots and the sample to be measured is viewed through the other aperture *via* the second slot in the base-plate.

The Photometer Head.

This is shown diagrammatically in Figure 2. It consists essentially of a prism A, the apex of which lies on a line joining the centres of two mirrors, B′ and B″. Beneath each of these mirrors is a "V" or "Cat's-eye" diaphragm in which the square aperture is capable of being varied in size in a symmetrical manner. The drums, C′ and C″, are calibrated from 0-100 in terms of the area of the apertures.

Considering one-half of the optical system, light reflected from the test surface passes (when the aperture is open) to the mirror and thence to the prism, one-half being reflected vertically. Part of this light then passes through the stop D and is viewed by means of the ocular E as one-half of a circular field. In order that the field brightness shall be proportional to the area of the aperture of the variable diaphragm, it is necessary that a ray from any point on the prism face traced backwards through any point on the edge of the aperture when fully open shall, when produced, fall within the illuminated portion of the test (or standard) surface. The mirrors B′ and B″ and the slots in the base plate are large enough (for any position of the photometer head within the range of the instrument) to fulfil these conditions.

The sliding filter holder (F) is arranged so that colour filters may be introduced into the optical axis above the stop in order to enable the half fields to be matched when examining coloured surfaces.

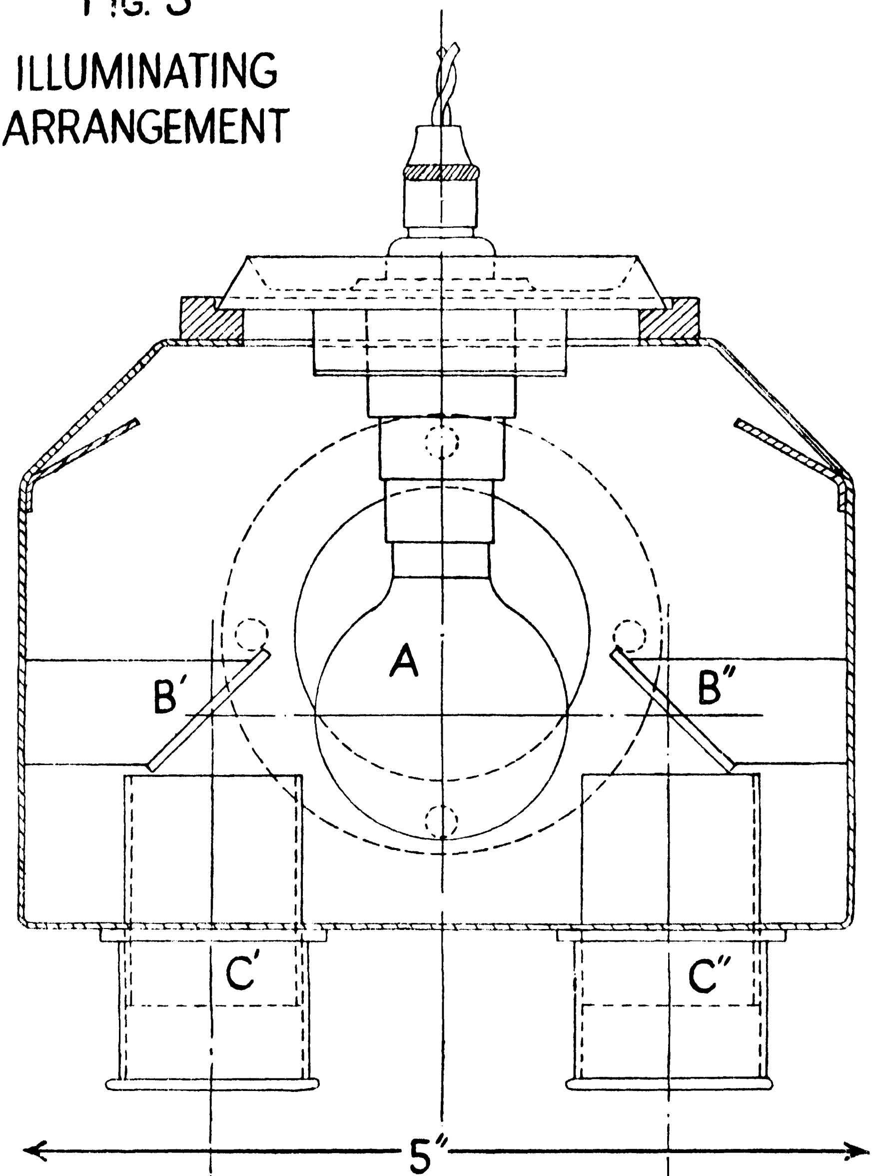
The Illuminating Arrangement.

This is shown in Figure 3.

A vertical filament gas-filled lamp (A) is so arranged in a ventilated metal housing that the centre of the filament lies on a line joining the centres of two mirrors (B′ and B″) placed at 45°. Approximately parallel beams of light are thus caused to emerge through two apertures, C′ and C″. The distance between the centres of the two apertures corresponds to that between the centres of the two slots in the base-plate. Provision is made for adjusting the position of the lamp in a horizontal plane by means of a circular plate with a bevelled edge and three set-screws. By making a series of measurements of the brightness of the test surface relative to that of the

standard white plate at a number of angles of observation for a given angle of incidence of the illuminating beams and plotting the relative intensity against angle of observation, a curve is obtained which depicts the lustre or gloss of the material. Such curves may be obtained for a number of angles of

FIG. 3
ILLUMINATING ARRANGEMENT



incidence of the illuminating beams. Klughardt and others[9,10,11] have discussed the evaluation of lustre numbers from the figures obtained.

From the dimensions given in the figures it will be seen that the instrument is compact. Its weight is such as to make it readily portable and measure-

ments with it may be carried out on a web of cloth without mutilation by the cutting of a sample.

The author's acknowledgments are due to Dr. W. H. Gibson, O.B.E., Director of Research of the Linen Industry Research Association, for his suggestions and interest in the work and thanks are due to Mr. R. J. B. Keig, for numerous suggestions connected with the mechanical design, and to Messrs. James Swift & Son, of London, for constructing an instrument.

The author is indebted finally to the Council of the Linen Industry Research Association for permission to publish this work.

SUMMARY.

1. A compact and portable instrument is described for the evaluation of the lustre of textile and other materials by comparing the brightness of the surface under examination with that of a standard white surface (barium sulphate) under the same conditions of illumination.

2. Provision is made whereby observations may be made at a number of angles for a given angle of incidence of the illuminating beams. In addition, the angle of incidence of the latter may also be varied.

3. Measurements may be carried out by placing the instrument on the test surface without the necessity of cutting a sample from the latter.

REFERENCES.

[1] Schulz. *Z. tech. Phys.*, 1924, **5**, 138.
[2] Desbleds. *Dyer*, 1930, **64**, 515.
[3] Ingersoll. *J. Opt. Soc. Amer.*, 1921, **5**, 213.
[4] Land. E.P.412,179, 1932.
[5] Pollard. *Nature*, 1936, **138**, 311.
[6] Schulz und Ewald. *Zellstoff und Papier*, 1926, **6**, 427.
[7] Pulfrich. *Z. Instr. Kunde*, 1925, **45**, 35 *et seq.*
[8] Boffey and Derrett-Smith. *J. Sci. Inst.*, 1931, **8**, 356.
[9] Klughardt. *Z. tech. Phys.*, 1927, **8**, 109.
[10] See also Naumann. *Z. tech. Phys.*, 1927, **8**, 239.
[11] Richter. *Zent. Ztg. Opt. Mech.*, 1928.

Received 29/4/37.

THE JOURNAL OF THE

TEXTILE INSTITUTE

TRANSACTIONS

20—STEREOSCOPIC RADIOGRAPHY OF CLOTH

H. F. SHERWOOD.

(Communication No. 626 from the Kodak Research Laboratories).

In a recent communication,[1] some preliminary experiments were reported on the possibility of radiographing samples of cloth with X-rays of relatively low penetrating power, generated at 4 to 12 kilovolts. The radiographs are made on fine-grained plates or films, and the negatives are then enlarged to 5 diameters or more in order to show the finer details. This method can disclose certain types of defects in weave or yarn, can distinguish between weighted and unweighted cloth, and can show the effect of crêping upon the weave.

The specimen to be radiographed is mounted over the photographic plate, Figs. 1 and 3 (which is suitably protected from light) and the X-rays are directed through the sample on to the plate. Such a radiograph is a form of shadow picture, producing an image whose gradations of light and shade correspond to the transparencies of the specimen for the X-rays. Such an image does not possess perspective or depth. While the path of the yarn in the weave can be followed in directions parallel to the plate, it is not possible to trace their wandering through the thickness of the cloth or to tell which threads pass over or under others.

Stereoscopic radiographs, however, make it possible for the observer to visualize clearly the paths of the various threads in relation to each other in the depth of the cloth as well as in its lateral extent. The effects of crêping, or other distortions of the threads, can also be viewed by this method. The stereoscopic radiographs of cloth are examined under sufficient enlargement or magnification so that the details of the weave can be observed without undue eyestrain (Figs. 5 and 6). The method promises to be of value in the analysis of complex weaves and in the study of weaving defects.

In customary binocular vision, the two eyes receive slightly different views of the object or scene under observation. For example, in looking at a tree, the right eye sees a little farther around the right side of the tree than does the left eye, while the left eye sees farther around the left side of the tree. The brain combines these two optical images to give the stereoscopic view which shows clearly the positions of various parts of the object or scene in space.

In viewing stereoscopic radiographs, the observer has the impression of seeing through the object, and at the same time seeing the various parts, all arranged in their proper positions in space.

The technique of stereoscopic radiography is simply to make two radiographs at a slightly different angle of the incident X-rays, so as to duplicate

the two views or projections which the eyes of the observer would have in looking at the object itself.

In examining small objects for fine detail, the most comfortable viewing distance is about 15 inches. The separation of the pupils of the eyes averages about 2·5 inches. In viewing an object at a 15-inch distance, the angular separation of the lines of vision of the eyes is about ten degrees. Stereoscopic radiographs of small objects may therefore be made by making two radiographs with two beams of X-rays ten degrees apart.

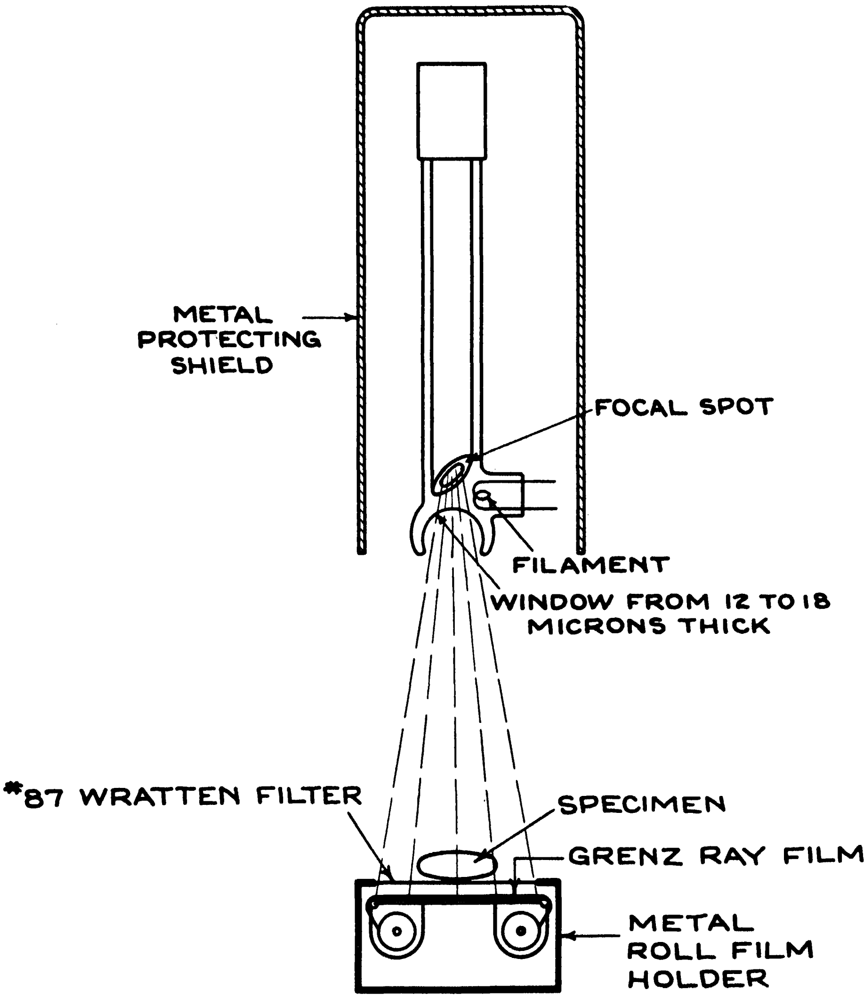


Fig. 1. Specimen to be radiographed mounted over photographic plate.

The object is kept stationary. The first radiograph is made with the central ray tilted five degrees to one side. After this exposure, the plate is replaced with a fresh plate, and the X-ray tube is shifted so as to tilt the central ray five degrees on the other side, making a total shift of ten degrees, and the second exposure is made.

When finished, these radiographs are mounted on the stereoscope so that the radiograph made with the right-hand position of the X-ray tube is viewed with the right eye, while that made with the left-hand position of

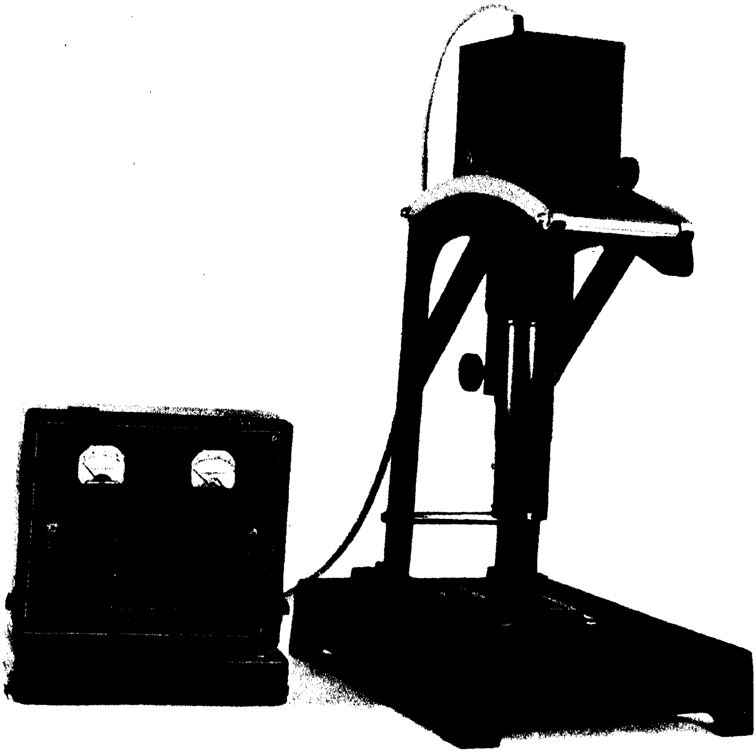


Fig. 3. Stereo soft X-ray apparatus.

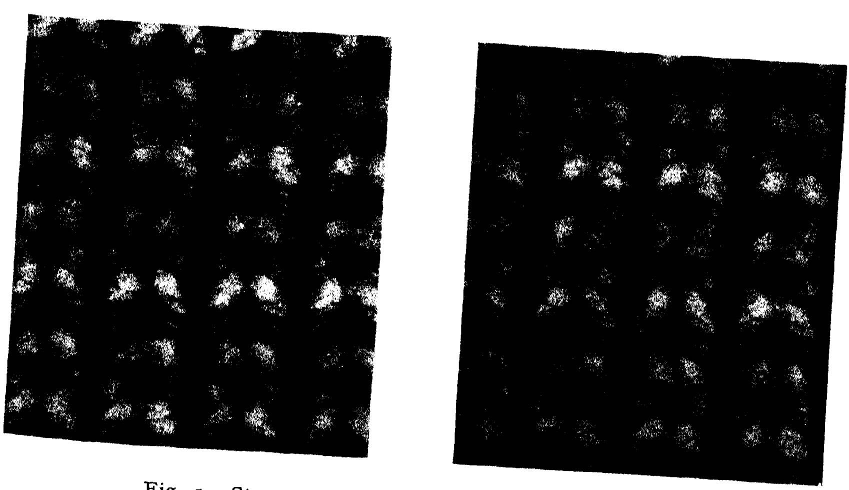


Fig. 5. Stereo pair of radiographs of knitted fabric.

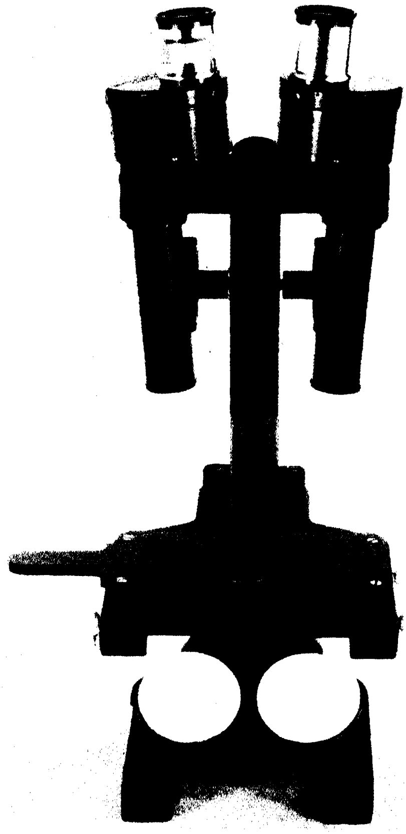


Fig. 4.
Special stereoscopic microscope.

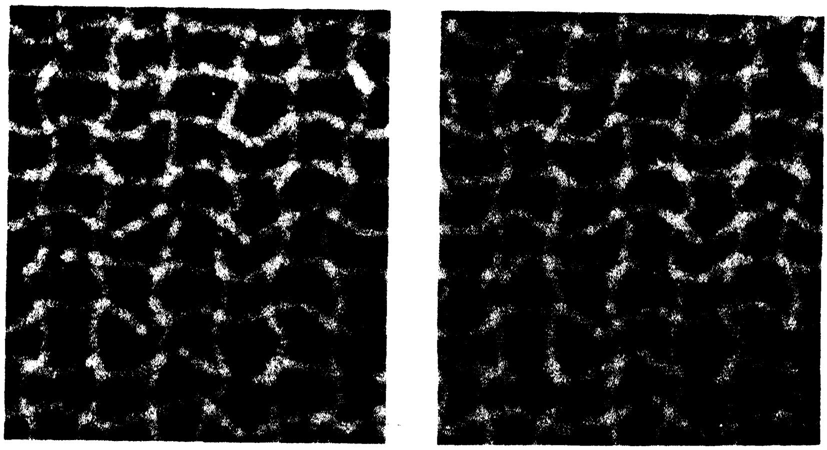


Fig. 6. Stereo pair of radiographs of crêpe fabric.

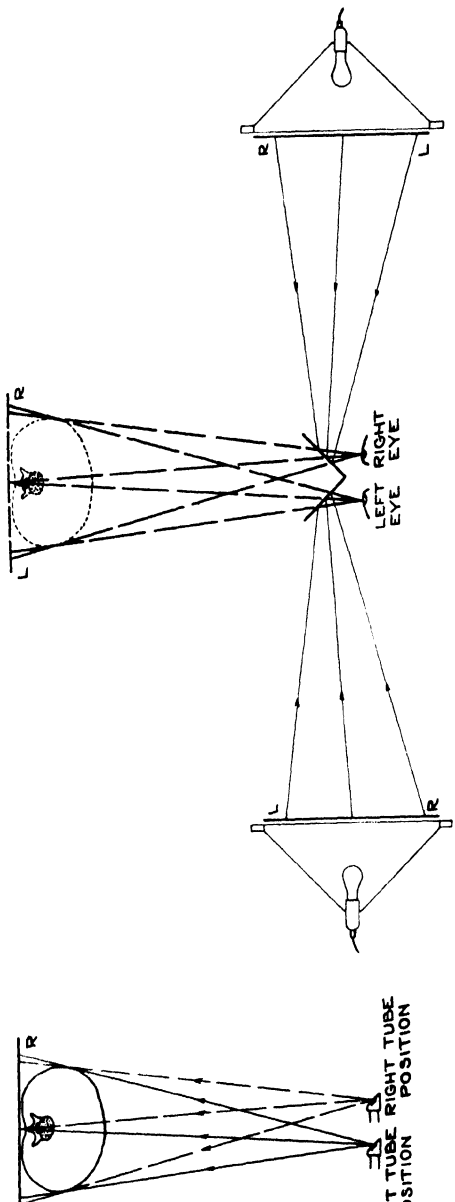


Fig. 2. Principle of stereoscopic radiography.

the tube is viewed by the left eye. When the two views are brought into register by suitable adjustments of the stereoscope, the stereoscopic impression results.

Fig. 2 illustrates the principle of stereoscopic radiography, showing the two positions of the X-ray tube in making the exposure, and the corresponding positions of the observer's eyes in viewing the radiographs.

Radiographs of cloths must be enlarged in order to distinguish their finer details. A low-powered (25 ×) stereoscopic microscope (Fig. 4) is now available that enables the observer to view negative images of the two radiographs stereoscopically. Satisfactory results may be obtained by photographic enlargements of the two stereoscopic radiographs, and viewing these in a suitable stereoscope. This method involves considerable time and skill.

In exposing the two stereoscopic radiographs at two positions of the X-ray tube, some portions of the object are displaced relative to other portions in the two views. In enlarging the radiographs, these displacements are similarly magnified and the resulting stereoscopic image retains all its spatial relationships, in depth and width and in the correct proportions.

In adjusting the stereoscope to fuse the two images, it is very helpful to have some marker or guide in the radiographs which can easily be recognized and brought into register. To serve as such a guide, a piece of fine wire is mounted over the sample of cloth to be radiographed. When the resulting radiographs are mounted in the stereoscope, the necessary adjustments are made to bring the wire shadows into register, and then the whole areas of the two radiographs fuse into each other almost automatically to give the stereoscopic view.

CONCLUSION.

The stereoscopic radiography of cloth should be particularly valuable in analysing complex weaves, since it provides a method whereby the weave, suitably enlarged, can be visualised in its correct spatial relationships.

REFERENCE.

[1] Sherwood, H. F., The Radiography of Cloth, *J. Text. Inst.*, 1936, **27**, T162-170, *Rayon and Melliand Textile Monthly*, **17**, 51-3, May, 1936.

Received 7/6/37.

Correspondence

YARN STRENGTH OF EGYPTIAN MIXINGS

SIR,

I have read with great interest, the paper on " Yarn strength of Egyptian Mixings," written by Mr. F. Dunkerley, A.T.I., and published in the August issue of the *Journal of the Textile Institute*. Mr. Dunkerley has written a very good paper, but I note the absence of any reference to Maared. This cotton would have provided the greatest contrast of staple lengths that could be obtained by the mixture of commercial growths, and its inclusion would have made the results much more significant to the spinner.

The samples have been spun on the " Casablanca " system, and when it is stated that direct experiment is required to substantiate these results on the more usual drafting system, one gathers that these experiments will possibly be made and the results will undoubtedly form the basis of a paper as interesting as the present one. As the writer of the paper suggests, it is likely that substantially parallel results to those recorded will be obtained, but I have had some considerable experience myself of an experimental plant, and I would like to remind Mr. Dunkerley that miracles can almost be performed on experimental machinery. I have made some experiments on the mixing of different growths of cotton of widely contrasting staple lengths, and whilst satisfactory yarns can be made in experiment on the usual roller system, the attempt to repeat them on a commercial scale necessitates a wider setting of rollers (or the use of a wider tensor on the Casablanca system) with an accompanying loss of regularity and strength, a larger number of roller laps and clearer laps, and the introduction of other undesirable yarn features which Mr. Dunkerley does not concern himself with, as of course they are not within the scope of his paper. I mention them because the paper suggests by inference that regularity of staple is not a primary requirement of the spinner. Yet it cannot be suggested that irregularity of staple is in any way an advantage to the spinner, who has afterwards to pay for the removal of the shorter fibres from the cotton, to be disposed of as waste at a much lower price. The paper rightly distinguishes between irregularity of staple and the presence of immature fibre, but the suggestion that mixing of high grade cottons of differing staple can have no evil effect on the resulting crop or the subsequent user, must have aroused a great deal of uneasiness in the minds of the many spinners who remember the time when Sakellarides was at its best, and the trouble that was foretold when Pillion was introduced. At that time Sakel was beginning to fall off, but the mixing of these two growths in Egypt, speedily resulted in the deterioration of them both, and the agitation thus created culminated in the passing of the Law No. 51, referred to in the paper. In view of the necessity of such a law, cotton users will be surprised to hear any further suggestion that different growths of cotton could be mixed in Egypt with impunity.

The danger is that the suggestions made in the paper, coming from a responsible body in Egypt, might lead to a relaxation of vigilance and the indiscriminate mixing of Egyptian types at a time when the Egyptian Ministry of Agriculture is making every effort to produce from Egypt a cotton that can worthily take the place formerly held by Sakel.

The spinners who buy the Egyptian crop will be best served by as uniform a product from the field as can be obtained, and any mixing of growths should be done on the individual spinner's responsibility, so that the trade as a whole does not have to abide by the consequences.

Oldham. 24/9/37. (*Signed*) J. PILKINGTON, A.T.I.

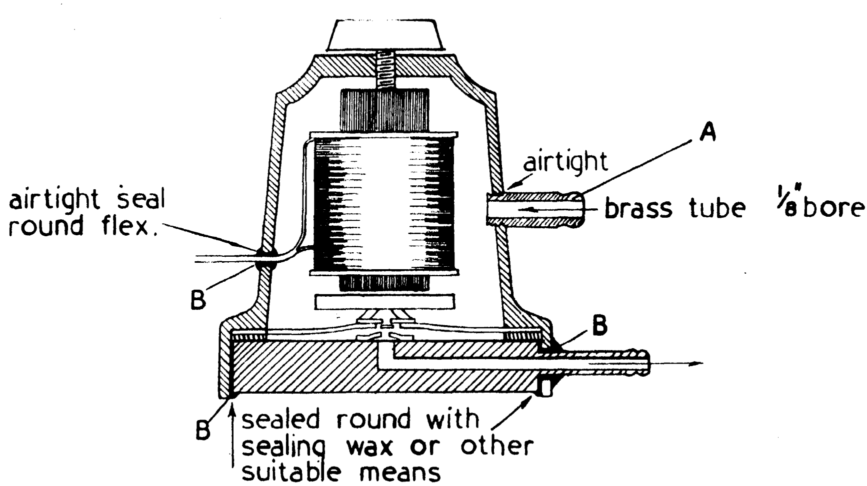
A RAPID METHOD OF DETERMINING THE MOISTURE CONTENT OF TEXTILES

SIR,

In view of a number of enquiries from people wishing to construct the apparatus described in our paper under the above title published in the *Journal of the Textile Institute* (1936, 27, T219-228) we should like to add a short note describing more fully certain points in the construction and operation of the apparatus.

In the above paper it was mentioned that a " Dinton Aerator " could be modified to act as a pump for re-circulating air round the system. The " Dinton Aerator " as manufactured is a circulating pump, provided with an outlet tube, the supply of fresh air being drawn in through spaces in the case and around the base of the pump. The figure shows a sectional view of the modified pump. The modification consists of fitting an inlet tube A into the case of the pump and sealing up the air inlets with sealing wax or other suitable means, as indicated by B. When modified in this manner the " Dinton Aerator " has been found to act as a very suitable re-circulating pump.

DIAGRAM OF MODIFIED DINTON AERATOR



The other point refers to the behaviour of the " Humatagraph " humidity indicator. It has been found that whilst the readings of the " Humatagraph " are reliable when the humidity of the air is increased from a low value to a higher value, the results are not always reliable when the humidity has been decreased unless the humidity to be measured is very low (i.e. 20 per cent. R.H. or less) when the " Humatagraph " responds normally and reads correctly. It has therefore been found advisable to run the apparatus with the tube A (see Fig. 1. in the original paper) empty, and with a drying tube of calcium chloride or other suitable material, in the air circuit for a few minutes between each test. The air is thus reduced to a very low humidity and the " Humatagraph " rapidly moves to its very low reading. When a fresh sample of the textile material is placed in the apparatus the humidity of the air is increased and the " Humatagraph " reads this humidity correctly and quickly.

Linen Industry Research Association, (*Signed*) J. A. MATTHEW.
Lambeg, N. Ireland, J. L. SPENCER SMITH.
21/9/37.

THE JOURNAL OF THE

TEXTILE INSTITUTE

TRANSACTIONS

21—THE EFFECT OF TWIST ON THE STRENGTH AND LENGTH OF COTTON FIBRE

By HARIRAO NAVKAL, M.Sc.
and NAZIR AHMAD, M.Sc., Ph.D., F.Inst.P.

SUMMARY

Five Indian cottons capable of spinning from 6's to 34's warp yarn were chosen, and in each case the fibre strength and the percentage contraction were measured with zero twist and after inserting 25, 50 and 100 turns both in the right-handed and left-handed directions. For strength tests, Barratt's apparatus, with certain modifications, was used, while the contraction was read on a micrometer in the eyepiece of a telescope. The mean humidity for each of these twists was kept nearly constant, to avoid applying large corrections on this account. The following conclusions are derived from a consideration of the results:—

(1) The frequency distributions of the strength values are best represented by Pearson's Type I curve, whether the tests are made on whole fibres or centimetre lengths. When the fibres are twisted, the form of the curve is unaltered.

(2) If all the results are combined it is found that the effect of left-handed twist is slightly greater than that of right-handed twist.

(3) For Cambodia Co. 1, mean fibre-strength is unchanged up to 25 turns after which it increases by a small amount and then remains steady for higher twist. For the other cottons the fibre strength increases with twist from the outset, reaches a maximum value and then falls as the twist is gradually increased. But the rates of change of strength and the points at which the maximum values are reached are different for the different cottons. The maximum increase in strength for these cottons lies between 3 and 9 per cent. of the value at zero twist.

(4) Parabolic curves were fitted to the strength values and it was found that all cottons reach their maximum fibre strength only after some 40 turns per inch are inserted, and that the longer cottons could withstand a higher degree of twist than the shorter ones before reaching their maximum fibre strength, the peak value for Cambodia Co. 1 occurring at about 200 turns per inch.

(5) At 100 turns per cm. (254 turns per inch), there is a considerable fall in fibre strength, which is greater for the shorter than for the longer cottons. At this high twist, the shortest cotton, *viz.*, A. 19, lost as much as 24 per cent. of its fibre strength, while the longest, Cambodia Co. 1, lost practically nothing.

(6) Direction of twisting has no effect on the variability of fibre strength. Variation in fibre strength is very nearly constant up to 50 turns per cm., but

at 100 turns per cm. it is significantly higher for all cottons except Cambodia Co. 1.

Furthermore this increase in strength variability at 100 turns is greater for the shorter than for the medium cottons. Thus, at high twists the fibres of these cottons are not only rendered weaker but also more variable in strength, and in both the cases the effects are greater with the shorter cottons.

(7) When twist is increased from zero to 25 or 50 turns per cm., the skewness of fibre strength distribution curve falls for some cottons and rises with others. The skewness at 100 turns, however, is significantly higher, being nearly twice the value for 50 turns for all cottons except Cambodia Co. 1.

(8) Direction of twist does not make any difference to the mean value of percentage contraction up to 50 turns per cm. At 100 turns, however, there is a tendency for the fibres to contract more with the right-handed than with the left-handed twist.

(9) Fibres of all cottons contract on being twisted, the percentage contraction increases rapidly after medium twist (25 turns) is inserted and is greater for the shorter than for the longer cottons.

(10) Variability in length increases appreciably only after 50 turns are inserted and the increase is greater for the shorter than for the relatively longer cottons.

(11) The correlation coefficient between the strength and the percentage contraction of fibre is practically zero. Hence it is inferred that in many cases the fibre does not break at its thinnest point, which may in fact be rendered stronger, up to a limit, by the insertion of twist, but at a point where mechanical or bacterial injury has taken place.

(12) Variability in the properties of the cotton fibre with twist is discussed, and it is shown that so long as the twist is within the limits usually employed in spinning yarn, it improves, on the whole, the properties of the individual fibres. However, this improvement in fibre-properties in general and in fibre strength in particular can account for only a very small fraction of the increase in yarn strength observed for the same range of twist.

(13) The bearing of these results on the molecular chain theory of the structure of cotton fibre is discussed, and it is found that this theory is capable of explaining, in a general way, the principal effects of twist on hair strength observed by us.

Various errors that could have crept into this investigation have been examined and their effect shown to be negligible in a comparative study of cottons.

INTRODUCTION

The earlier attempts to find a relation between yarn strength and fibre strength led to certain results which were either unexpected or anomalous. Monie[1] and Bowman[2], who first studied this problem, found that in ordinary yarns only about 20 per cent. of the combined strength of the fibres is utilised, the remaining 80 per cent. being lost to all intents and purposes. Turner[3], in a critical study of the subject, showed that an arithmetical error had crept in the works of both Monie and Bowman, and that, if this error is removed, the percentage of total fibre strength actually utilised in the yarns examined by them falls down to low figure of 10, which is probably due to insufficient data, large sampling error and inaccurate methods of measurement. Miss Clegg[4] made an important advance in the investigation of this problem and not only studied the relation between fibre strength and yarn strength, but

also ascertained by employing Bright's Congo Red technique, the percentages of fibres which had broken and those which had slipped in the rupture of the yarn. Her experiments showed that about 40 per cent. of the total fibre strength may be utilised in the yarn strength, but, curiously enough, the natural corollary of this result that cottons with high fibre strength should yield comparatively stronger yarns, was not borne out by her observations, which failed to establish any correlation between hair strength and yarn strength. Turner[5], working with Indian cottons, confirmed Miss Clegg's conclusion as regards lack of correlation between these two properties, but showed further that if due allowance is made for the fineness of the fibre, and consequently, the number of fibres present in an average cross-section of the yarn, the negative correlation between hair strength and yarn strength is converted into a positive one, though it is still insignificant. This work was later extended by Turner and Venkataraman[6], who on analysing the results for 95 samples of standard Indian cottons, found that the *partial* correlation-coefficient between fibre strength and spinning value was only 0·10 as against 0·70 for mean fibre length.

It should be stated here that, in the experiments to which a brief reference has been made above, soft or moderately hard twisted yarns were employed. It was shown by Gulati and Turner[7] that if hard twisted yarns were used the percentage of total fibre strength utilised in the yarn rose to high values. Miss Clegg had earlier emphasised the necessity of distinguishing between the respective rôles of fibre-breakage and fibre-slippage in the rupture of yarn. Gulati and Turner gave quantitative data to show how one factor waned and the other waxed as more and more twist was inserted in the yarn, until at about 30 turns to the inch, the fibre slippage was reduced to insignificance. These conditions, however, held for special hard twisted yarns, while for the ordinary yarns, which are of general commercial importance, it was still true that 40 to 60 per cent. of the fibres did not make any *perceptible* contribution to the strength of the yarn. Turner has discussed at length the various factors which might be held responsible for this observed lack of agreement between total hair strength and yarn strength.

One of the factors which, it was thought, might throw some light on the problem and was capable of being studied experimentally, was the effect of twist on the strength and extension of cotton fibre. As is well known, in the measurement of hair strength, care is taken that the fibre is *not* twisted, while in the manufacture of yarn the fibres have to be twisted to give cohesion and strength to the yarn. It can be shown that if n be the number of turns per inch in the yarn then the angle α which the fibres make with the yarn axis is given by

$$n = \tan \alpha / d$$

where d is the diameter of the yarn in inches. So far as we know, the precise effect on its strength of twisting the fibre by a known amount has not been studied before. It was, therefore, an unknown factor in the consideration and elucidation of this important problem. Accordingly, it was thought desirable that a study of this factor should be made for a number of representative standard Indian cottons and the results of this study are described in this Bulletin. The study began, as stated above, with the object of throwing light on an hitherto obscure corner in the problem of relation between hair strength and yarn strength, but, as it developed, it yielded interesting and promising results in several directions, and our only regret is that, owing to the highly time-absorbing nature of the experiments, we have not been able to extend it to a larger number of cottons.

DESCRIPTION OF APPARATUS

The apparatus used in these tests consisted of three parts, (1) for recording the breaking strength of the fibres, (2) for inserting in the fibres the desired degree of twist, and (3) for measuring the contraction of fibres due to the insertion of twist. For the first, Barratt's fibre balance, with certain modifications, was used. As a description of this apparatus has been given by Barratt[8] and by Navkal and Sen[9], it is unnecessary to give it here in detail. Briefly, it consists of a balance, whose beam, instead of supporting two pans, supports at one end an iron rod E (Fig. 1) and at the other a metallic hook CB. The rod E passes through a central hole in a solenoid S and the

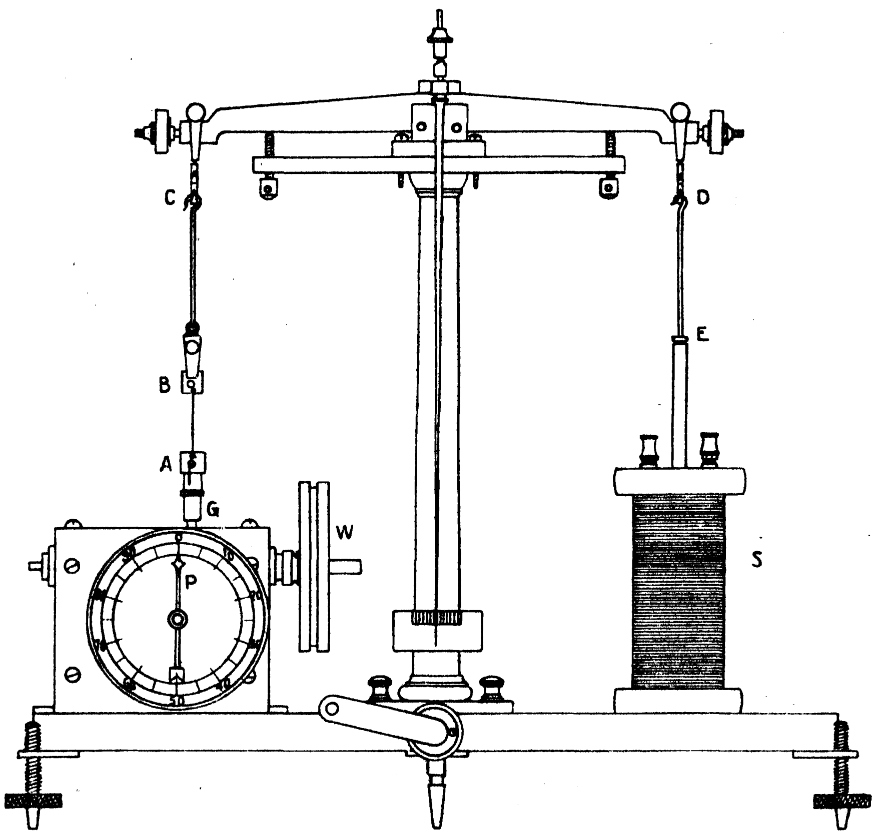


FIG. 1

attraction between the rod E and the solenoid S, which is a function of the current in the latter, supplies the tension on the fibre. The fibre is mounted on two eyelets, one of which is placed at the hook end B and the other is held by another hook A which can be raised or lowered at will and forms part of the reduction gear GPW. By means of this gear arrangement which is driven by a motor, the fibre can be twisted, either clockwise or anti-clockwise, to any desired degree and the number of turns inserted is shown by the pointer at P. After the required turns have been inserted in the fibre, a small current is made to flow through the solenoid. This current is gradually increased till the fibre breaks, its value at the breaking point is read from a milliammeter placed in series in the circuit, and the breaking strength of the fibre is noted

from a calibration table. The motor was run at 1,450 r.p.m. and the fibres were twisted at the rate of 15 to 20 turns per minute. The change in length with twist is read on a micrometer scale in the eyepiece of a telescope focussed on it.

The rod XX^1 (Fig. 2) which forms the axle of the wheel W carries a worm W_1, which is meshed with the teeth of a gear wheel T_1. It is the axle (YY^1) of this wheel (T_1) that carries the hook at A and in addition carries a worm W_2, which in its turn is meshed with the gearing wheel T_2. The pinion wheel P_1 and the toothed wheel T_2 have a common axial rod ZZ^1 and as P_1 and T_3 are geared, axle 33^1 rotates at a known speed ratio and the (P) pointer is easily made to indicate the number of turns inserted in the fibre at A. The main purpose of this box is to move the plane of rotation through 90° and to decrease the speed of rotation, so that the turns are inserted without breaking the fibre.

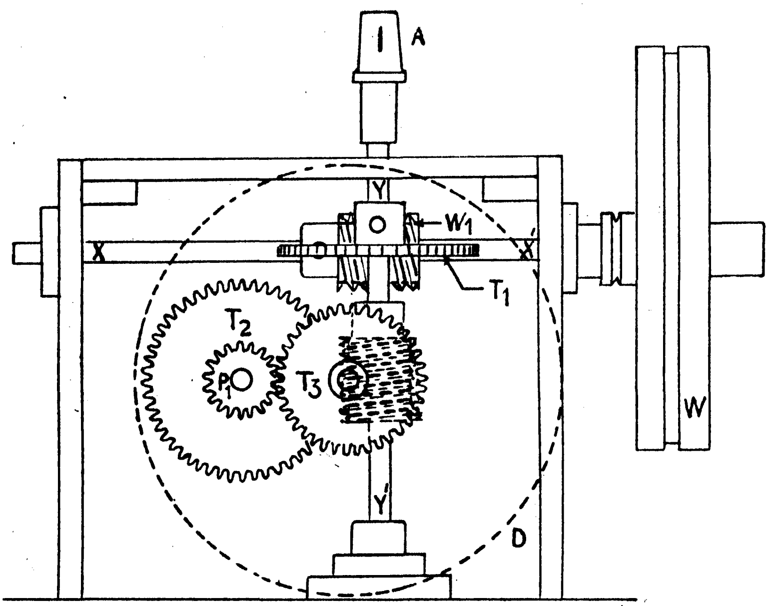
Method.

From each cotton, a representative sample was obtained by dividing the heap into several parts, drawing a tuft from each part and mixing the tufts well by hand. This sample was made into a hand sliver and from this sliver were taken seven sections which we shall call A, B, C, D, E, F and G. The direction and amount of twist given to fibres taken from each of these seven before they were broken were as follows:

Section.	Number of turns.	Direction.
A	Nil	—
B	25	Clockwise.
C	25	Anti-clockwise.
D	50	Clockwise.
E	50	Anti-clockwise.
F	100	Clockwise.
G	100	Anti-clockwise.

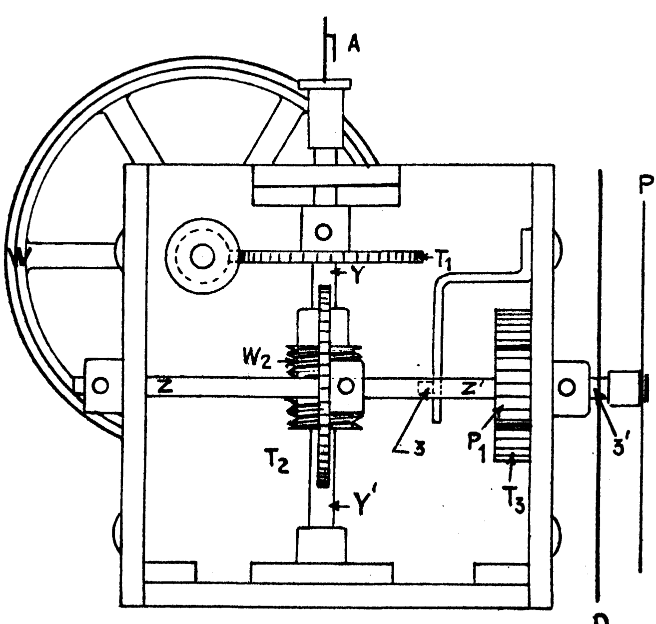
From each section, 500 fibres were taken for strength tests, thus making a total of 3,500 fibres for each cotton. For percentage contraction, however, it was found sufficient to examine about 100 fibres with low twist and about 300 fibres with 100 turns inserted in them. All the 500 fibres from each section were not tested consecutively, but, on the other hand, a few fibres from A were tested first, then a few fibres from B, C, . . . G. In the second cycle a few more fibres from A were tested first, followed by tests on fibres from sections B, C, etc. These cycles were continued until the tests were complete. This was done in order to eliminate the effect of variation in humidity as will be explained in the next section. Due care was taken to see that the different sections A, B, C, etc., were kept separate and that all the fibres taken from them were exhausted. Unless the latter precaution is taken, there is a likelihood of a bias in favour of the good fibres and a danger of rejecting the weak fibres.

It should be noted that, as pointed out by Schwendinger,[10] the weight recorded in Barratt's balance is the breaking strength of a fibre $+x$, where x is the small weight required to change the position of the pointer from zero to the point at which the fibre breaks, i.e., through a distance equal to the extension of the fibre. The extension of a few fibres was measured and was found to be of the order of 7 per cent. agreeing with the value given by Barratt[11] and Collins.[12] Hence, the extension in this case is about 0·07



FRONT ELEVATION

FIG. 2.



SIDE ELEVATION

FIG. 2.

cms., and the weight required to deflect the beam through this distance is less than 0·1 gms. This weight remains very nearly constant in all the determinations and disappears in the differences with which we are mainly concerned in this paper. Some of the weaker fibres break in the act of twisting, before any tension is applied. The exclusion of such fibres would slightly raise the mean. It was found that a very small number behaved in this manner and they were noted down as possessing zero strength.

Effect of Humidity.

Perhaps the most important precaution that should be taken in tests of this nature is to see that the effects of humidity do not mask those of twist. This is essential in view of the fact that the rate of change of strength with humidity is high. Apart from the work of Willcomm[14] (a), the effect of humidity on fibre strength has been studied by Mann[13] and one of the authors in collaboration with Dr. Turner.[14a] Mann's mean curve (Fig. 2 in his paper) shows that the fibre-strength increases more or less in a linear ratio up to a relative humidity of 75 per cent. after which it remains practically constant. Similar results were obtained by the author for Indian cottons. We may, therefore, regard it as fairly definite that the humidity strength curve for cotton may be split up into two straight lines as shown in Fig. 3, where AB represents the portion in which strength changes rapidly

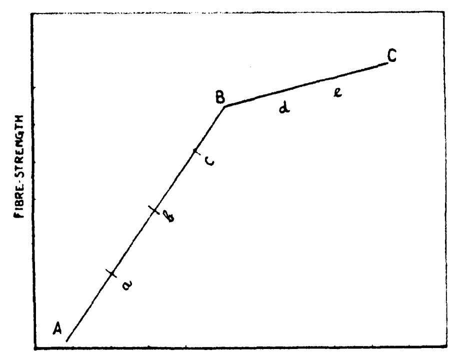


FIG. 3

with humidity and BC the portion in which it remains nearly constant. Now, if all the tests for a certain twist θ_1 are made when the atmospheric humidity lies in the region ab, while all the tests for another twist θ_2, are carried out when the humidity has altered to lie in the region bc or de, then evidently the results of the two tests are not directly comparable unless we know exactly what part of the increase in strength is due to change in humidity. As this would have required a separate and prolonged investigation, it was decided that the best course would be to spread out the tests *in time*. This was done by testing a small number of fibres for each of the three twists and for no twist consecutively when the humidity was very nearly the same, so that the correction on account of humidity on each occasion, was very small. This method worked extremely well, as sudden and large fluctuations in humidity are not very common in Bombay. For the small changes in humidity, corrections, wherever necessary, were applied.

(*a*) Quoted by Mann. Willcomm found that the strength increased up to 80 per cent. R.H. It should, however, be noted that he broke bundles of hairs instead of individual fibres.

When, on the other hand, the humidity was found to be fluctuating rapidly, the tests were suspended until it became fairly constant. One advantage of working at fairly constant humidities is that the variation in ribbon width is small, and, therefore, the changes in strength may be taken as equivalent to changes in intrinsic strength.

Effect of Temperature.

In Bombay during the working hours the temperature fluctuations are generally small, being confined mostly to the range of 72° F. to 88° F. So far as we know, variation of fibre-strength with temperature has not been studied, but from the results obtained by Urquhart and Williams[15] it is known that within this limit fibre-weight varies only by about 0·2 per cent. when the humidity is constant. It may, therefore, be assumed that neither the length nor the strength of the fibres would be affected to an appreciable extent by small fluctuations in temperature. Therefore, no corrections were applied.

Material.

For the purpose of these tests five Indian cottons, namely, Cambodia Co. 1, Verum 262, Banilla, Mollisoni and Aligarh A 19 were selected. These cottons are very thoroughly tested each year (except Banilla) at the Technological Laboratory and the results of the latest tests, together with those for the earlier seasons, will be found in another Bulletin. Their chief fibre properties and spinning values are shown in Table I in which they have been arranged in the order of their spinning values which also happens to be that of their mean fibre length. It will be seen that they belong to different botanical species and cover practically the whole range of Indian cottons as regards staple length or spinning value. It should be mentioned that the values given in this table are both in British and C.G.S. units. In the succeeding tables the values are given only in the C.G.S. units, as the balance was calibrated only by using gram weights and a conversion to British units was thought unnecessary.

Table I.

Cotton	Highest standard warp count	Length		(f) Fibre weight		(s) Mean strength at 70 per cent. R.H.		Intrinsic strength s/f	
		in.	mms.	10^{-6} oz. per in.	10^{-6} gms per cm.	Oz.	Gms.	English units	C.G.S. units
Co. 1 (*G. Hirsutum*)	34	0·89	22·6	0·146	1·63	0·154	4·37	1·05	2·68
Verum 262 (*G. Verum*)	23	0·82	21·0	0·180	2·01	0·201	5·70	1·12	2·84
Banilla (*G. Cernuum* x *G. Indicum*)	16	0·76	19·2	0·159	1·78	0·218	6·18	1·37	3·47
Mollisoni (*G. Indicum*)	8	0·69	17·5	0·272	3·04	0·204	5·78	0·75	1·90
Aligarh 19 (*G. neglectum*)	6	0·64	16·3	0·262	2·93	0·198	5·61	0·76	1·91

NOTE.—The strength values have been obtained on the Barratt fibre balance and hence are likely to be somewhat higher than those got by the Balls or O'Neill Hair Testers, as shown by Navkal and Sen.[16]

Symbols.

In order to avoid repetition, the symbols used in this paper are here defined :—

θ_I = Twist (turns per cm.) inserted in a fibre.
θ_R = Twist in right-handed direction or clockwise.
θ_L = Twist in left-handed direction or anti-clockwise.
W = Breaking strength in grams.
W_θ = Breaking strength in grams for θ turns
K_θ = Percentage contraction after the insertion of θ turns.
h = Humidity percentage.
σ = Standard deviation.
e = Probable error of single observation.
$e(\%)$ = Probable error expressed as percentage of the mean.

RESULTS

These are discussed under the following heads :—

I. Effect of twist on mean fibre strength.
II. Effect of twist on fibre strength variation.
III. Variation of skewness and the type of curve for strength values with different twists.
IV. Change of mean length with twist.
V. Effect of twist on fibre length variation.
VI. Relationship between fibre strength and percentage contraction.
VII. The part played by twist in the fibre during the spinning process.
VIII. Variation of fibre strength with twist in relation to fibre structure.

I. Effect of Twist on Mean Fibre Strength.

The experimental results obtained are given in Table II. The mean strength has been reduced to a common humidity for the purpose of comparison. The mean humidity for each twist and this common humidity have been given side by side in the fifth and sixth columns so that it can be seen that the correlation is practically negligible.

It is well known that when the sap inside the cotton hairs dries up convolutions are formed, which are right-handed in some parts of the hair and left-handed in others. Recently Roehrich[17] has shown that when collodion tubes filled with water are dried in the oven, they produce spiral shaped ribbons similar to cotton fibres. According to him " the direction of the twisting is invariably controlled by that of the fibrillar spiral of the secondary membrane of the cell wall." Clegg and Harland[18] observed that in one cotton the left-handed convolutions occurred more frequently than the right-handed ones. Some preliminary observations made in this Laboratory showed that one kind of convolution occurs more often than the other in some Indian cottons. Therefore, if the fibres of the different cottons were twisted only in one direction (say left-handed), those cottons (if any) in which the convolutions occurred more frequently in the same direction would be tested under more favourable conditions than those in which the convolutions occurred equally frequently in both directions or more frequently in the opposite (right-handed) direction. The results for these two types of cottons would not be strictly comparable. To avoid any such error creeping into the results, the fibres were twisted in both directions. If the results for the two directions of twist agree within the experimental errors the mean could be taken for further analysis. If, on the other hand, the results differ by significant amounts, due allowance could be made for the effect of natural twists on convolutions present in the fibres. The differences in the strengths for the twists in the two directions are given in Table III.

Table II.

Cotton	Twist	Mean Strength (gms.) at the common humidity.	Number tested.	Common Humidity.	Mean Humidity.
Cambodia Co. 1	0	4·15 ± 0·07	500	60	60
	25R	3·92 ± 0·07	500	60	60
	25L	4·29 ± 0·08	500	60	61
	50R	4·38 ± 0·08	502	60	60
	50L	4·32 ± 0·08	500	60	60
	100R	4·29 ± 0·07	501	60	60
	100L	4·28 ± 0·07	512	60	60
Verum 262 ...	0	5·53 ± 0·08	533	64	64
	25R	5·63 ± 0·08	530	64	64
	25L	5·96 ± 0·08	530	64	65
	50R	6·17 ± 0·09	530	64	65
	50L	5·90 ± 0·09	530	64	64
	100R	5·04 ± 0·09	530	64	65
	100L	5·45 ± 0·09	530	64	65
Banilla ...	0	6·09 ± 0·10	510	67	67
	25R	6·38 ± 0·10	508	67	67
	25L	6·18 ± 0·10	508	67	68
	50R	6·02 ± 0·10	508	67	66
	50L	5·80 ± 0·10	508	67	67
	100R	5·10 ± 0·09	508	67	68
	100L	5·42 ± 0·10	508	67	67
Mollisoni ...	0	5·72 ± 0·08	500	68	68
	25R	5·88 ± 0·08	500	68	68
	25L	6·04 ± 0·09	502	68	68
	50R	5·97 ± 0·09	502	68	68
	50L	6·02 ± 0·09	504	68	68
	100R	4·60 ± 0·08	500	68	69
	100L	4·92 ± 0·09	505	68	68
Aligarh A.19...	0	5·50 ± 0·09	521	66	66
	25R	5·48 ± 0·09	520	66	66
	25L	5·84 ± 0·10	520	66	66
	50R	5·64 ± 0·09	529	66	66
	50L	5·59 ± 0·10	520	66	66
	100R	4·19 ± 0·08	523	66	66
	100L	4·17 ± 0·09	526	66	66

Table III—Percentage Differences.

Cotton	W_{25R} − W_{25L}		W_{50R} − W_{50L}		W_{100R} − W_{100L}		
Co. 1	−8·9	(2·7)*	+1·4	(2·7)	+0·2	(2·4)	−7·3
Verum 262	−6·0	(2·0)	+4·9	(2·3)	−7·4	(2·3)*	−8·5
Banilla	+3·3	(2·3)	+3·6	(2·3)	−5·3	(2·1)	+1·6
Mollisoni	−2·8	(2·1)	−0·9	(2·3)	−5·6	(2·1)	−9·3
A. 19	−6·6	(2·5)	+0·9	(2·4)	+0·2	(2·2)	−5·5

(The basis for calculating the percentages is the value for no twist. Probable errors are given in brackets.)

It will be seen that in 8 cases the values for the left-handed twist are greater than those for the right-handed twist (negative difference) while in the remaining 7 cases they are less (positive differences). However, in spite of the fact that these numbers are nearly equal, the differences are on the whole much larger in the former than in the latter case, the average difference for the former being 5·4 as against only 2·1 for the latter. It would thus appear that the insertion of a left-handed twist in the fibre has, on the average, a greater effect in modifying the strength of the fibre than the insertion of an equal amount of right-handed twist. This effect is

brought out in a more striking manner if we consider the algebraic sum of the differences for each cotton separately shown in column 5 of Table III. We note from it that for four out of five cottons the values for the left-handed twist exceed those for the right-handed twist, while for one cotton—Banilla—although the reverse is the case, the difference is small. Thus, the larger effect on the strength of the fibre of the insertion of left-handed twist is common to long, medium and short-stapled Indian cottons tested in these experiments.

If we now consider the significance of the individual differences by applying the standard error criterion, we find that only in the two cases marked with an asterisk are they significant, while in the remaining 13 cases they are either insignificant or on the border-line. Continuing this with the preceding discussion we conclude that although the difference between the effect of left and right-handed twist on fibre strength is statistically insignificant in most cases, yet there is a marked tendency for the left-handed twist to give greater values of fibre strength than the right-handed twist and that this effect is shared by the different types of cottons tested in these experiments.

We shall now consider the effect on its strength of progressively inserting higher twist in the fibre. For this purpose, we shall first take the mean values for the left-handed and the right-handed twists to enable us to draw general conclusions and will follow it up by considering also the values for each direction of twist when we shall judge the significance of the differences. The mean values are given in Table IV.

Table IV.

Cotton	W_0 (Gms.)	W_{25} (Gms.)	W_{50} (Gms.)	W_{100} (Gms.)
Co. 1	$4{\cdot}15 \pm 0{\cdot}07$	$4{\cdot}10 \pm 0{\cdot}05$	$4{\cdot}35 \pm 0{\cdot}06$	$4{\cdot}28 \pm 0{\cdot}05$
Verum 262 ...	$5{\cdot}53 \pm 0{\cdot}08$	$5{\cdot}80 \pm 0{\cdot}06$	$6{\cdot}04 \pm 0{\cdot}06$	$5{\cdot}24 \pm 0{\cdot}06$
Banilla ...	$6{\cdot}09 \pm 0{\cdot}10$	$6{\cdot}28 \pm 0{\cdot}07$	$5{\cdot}91 \pm 0{\cdot}07$	$5{\cdot}26 \pm 0{\cdot}07$
Mollisoni ...	$5{\cdot}72 \pm 0{\cdot}08$	$5{\cdot}96 \pm 0{\cdot}06$	$6{\cdot}00 \pm 0{\cdot}06$	$4{\cdot}76 \pm 0{\cdot}06$
A. 19	$5{\cdot}50 \pm 0{\cdot}09$	$5{\cdot}66 \pm 0{\cdot}07$	$5{\cdot}62 \pm 0{\cdot}07$	$4{\cdot}18 \pm 0{\cdot}06$

In this table the cottons have been arranged in the order of their mean fibre length. A cursory glance at this table will show that these cottons exhibit interesting differences in their response to the action of twist on fibre strength, which appears to be related to their quality. The longest among them, Cambodia Co. 1, behaves somewhat differently from the others inasmuch as its fibre strength undergoes practically no change up to 25 turns, increases slightly at 50 turns, after which it remains approximately constant. In the remaining four cottons, the fibre strength rises and then falls as the twist is increased, but the rates of change of strength and the points at which the peak values are obtained are different for the different cottons. In Verum 262, which follows Cambodia Co. 1, the fibre strength steadily increases up to about 50 turns and then declines, its value for 100 turns begin less than that for zero twist. In Banilla, which takes the third place in respect of staple length, the increase in fibre strength proceeds only up to about 25 turns, after which there is a steady decline, its values both for 50 and 100 turns being less than that for zero twist. In the two shortest cottons in this series, namely Mollisoni and Aligarh A. 19, the fibre strength increases on inserting 25 turns, remains practically constant for 50 turns,

but falls precipitately when 100 turns are inserted in the fibre. These cottons may, therefore, be divided into the following four types:

	Low twist.	Medium twist.	High twist.
Type 1	No change	Slight increase	Constant
Type 2	Increase	Increase	Decrease
Type 3	Increase	Decrease	Decrease
Type 4	Increase	Constant	Decrease

This differential behaviour of the cottons as shown by the trends discussed above and its relationship to their quality is also brought out in a remarkable manner if we consider the percentage decrease in fibre-strength on the insertion of 100 turns, taking the value for zero twist as the basis. The relevant data are shown in Table V from which it will be seen that the percentage fall in fibre strength increases steadily as we go down the table from the long to the short stapled cottons.

Table V.

Cotton	$\frac{100\,(W_{100}-W_0)}{W_0}$	ϵ (%)
Co. 1	3·1	2·2
Verum 262	− 5·2	1·8
Banilla	−13·6	2·0
Mollisoni	−16·8	1·7
A.19	−24·0	2·0

So far we have considered the general trend of values without taking into account the significance of differences between them. To enable us to do so Table VI has been constructed in which the percentage differences between the values of strength obtained before and after inserting different twists in the fibre are shown together with the corresponding values of the probable error. The values in this table are given both for the right and the left-handed twist as well as for the means of the two directions, and the significant differences are marked with an asterisk.

We have seen above that as twist is inserted in the hairs, the fibre strength of these cottons increases up to a point beyond which in general it falls. In order to find the point for each cotton at which the maximum strength is attained, the experimental mean values of fibre strength have been plotted against twist in the graph in Fig. 4. Owing to the laborious nature of the tests it was not possible to have many more points and therefore the ordinary method of fitting the curves did not prove very helpful. However, taking the analogous case of the variation of yarn strength with twist, an attempt has been made to fit parabolae of the second order of the type given by the equation,

$$W=ax^2+bx+c \text{ (where } x=\theta/25).$$

From the values given in Table VII, the two constants a and b can be calculated and the point of maximum strength in each case is given by

$$dW/dx=o$$

or

$$+2ax+b=o \text{ i.e. } x=\frac{-b}{2a}$$

Table VI. Percentage Differences.

(e % are given in brackets)

Cotton		Mean result.			R. twists only.			L. twists only.		
		W_{25}	W_{50}	W_{100}	W_{25R}	W_{50R}	W_{100R}	W_{25L}	W_{50L}	W_{100L}
Co. 1	W_0	– 1·2 (2·2)	4·8 (2·2)	3·1 (2·2)	– 5·5 (2·4)	5·5 (2·6)	3·4 (2·4)	3·4 (2·6)	4·1 (2·6)	3·1 (2·4)
	W_{25}		6·0 (1·9) †	4·3 (1·7)		11·0 (2·6)*	8·9 (2·4)†		0·7 (2·6)	– 0·2 (2·6)
	W_{50}			– 1·7 (1·9)			– 2·2 (2·6)			– 1·0 (2·6)
Verum 262	W_0	4·9 (1·8)	9·2 (1·8) *	– 5·2 (1·8)	1·8 (2·0)	11·6 (2·2) *	– 8·9 (2·2) *	7·9 (2·0) †	6·7 (2·0) †	– 1·4 (2·2)
	W_{25}		4·3 (1·4) †	–10·1 (1·4) *		9·8 (2·2) *	–10·7 (2·4) *		– 1·1 (2·2)	– 9·2 (2·2)*
	W_{50}			–14·5 (1·4) *			–20·4 (2·4) *			– 8·1 (2·4)†
Banilla	W_0	3·1 (2·0)	– 3·0 (2·0)	–13·6 (2·0) *	4·8 (2·3)	– 1·1 (2·3)	–16·2 (2·3)*	1·5 (2·3)	– 4·8 (2·3)	–11·0 (2·1)*
	W_{25}		– 6·1 (1·6)†	–16·7 (1·5)*		– 5·9 (2·3)	–21·0 (2·3)*		– 6·2 (2·3)	–12·5 (2·1)*
	W_{50}			–10·7 (1·5)*			–15·1 (2·3)*			– 6·2 (2·1)*
Mollisoni	W_0	4·2 (1·7)	4·9 (1·7)	–16·8 (1·7)*	2·8 (1·9)	4·4 (2·1)	–19·6 (1·9)*	5·6 (2·1)	5·2 (2·1)	–14·0 (2·1)*
	W_{25}		0·7 (1·4)	–20·9 (1·4)*		1·6 (2·1)	–22·4 (1·9)*		– 0·3 (2·3)	–19·6 (2·3)*
	W_{50}			–21·8 (1·4)*			–23·9 (2·1)*			–19·2 (2·3)*
A.19	W_0	2·9 (2·2)	2·2 (2·2)	–24·0 (2·0)*	–0·4 (2·4)	2·5 (2·4)	–23·9 (2·2)*	6·2 (2·4)	1·6 (2·4)	–24·2 (2·4)*
	W_{25}		– 0·7 (1·8)	–26·9 (1·6)*		2·9 (2·4)	–23·4 (2·2)*		– 4·5 (2·5)	–30·4 (2·4)*
	W_{50}			–26·2 (1·6)*			–26·4 (2·2)*			–25·8 (2·4)*

†Slightly significant. *Highly significant.

The twist at which maximum strength occurs and the values of maximum strength are shown in Table VII.

Table VII.

Cotton	Maximum value occurs at $\theta=$ (calculated)	Maximum value in gms. (calculated)	Increase in strength %	$\frac{W_m - W_0}{W_0}$ (Actually obtained).
Co. 1	84	4·30	4·6	4·8
Verum 262	45	5·98	8·7	9·2
Banilla	15	6·16	0·3	3·1
Mollisoni	34	6·04	5·9	4·9
A. 19	28	5·72	4·4	2·9

$m=25$ for A.19 & Banilla and 50 for the rest.

It will be seen that the longer cottons can stand a much higher degree of twist than the shorter ones before attaining the maximum fibre strength. Except for Banilla, which is anomalous, the amount of twist necessary to give the maximum fibre strength diminishes steadily as we go down the

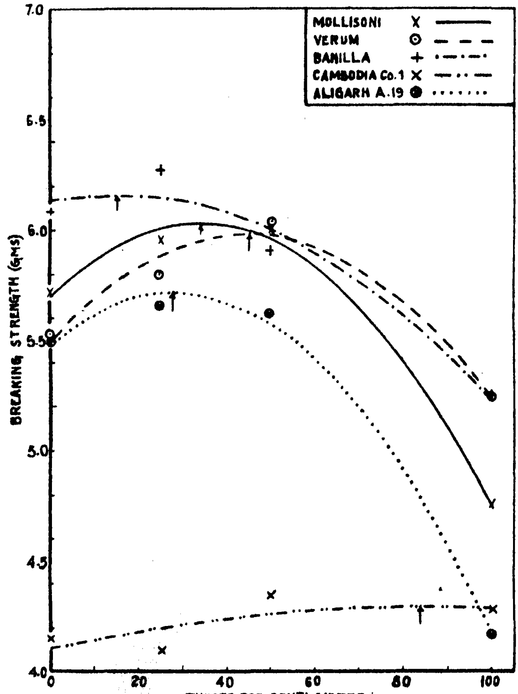


FIG. 4.

table in which the cottons are arranged in the order of the staple length. Furthermore, it will be remembered that the percentage decline in fibre strength resulting from the insertion of the highest degree of twist was much greater for the shorter than for the longer cottons, being 24 per cent. for A. 19 as against only 5·2 per cent. for Verum 262. In sharp contrast to this, the percentage increase in fibre strength at the peak value is very nearly the same for the three cottons, Cambodia Co. 1, Mollisoni and A. 19, somewhat greater for Verum 262, and rather small for Banilla. Thus, although the maximum fibre strength may be attained at very different

twists in the case of the long and the short cottons, the percentage increase in fibre strength at the peak is not very different for these cottons. Finally, it is to be noted that in the case of all cottons, the maximum strength occurs after 15 turns per cm., have been inserted.

II. Effect of Twist on Mean Fibre Strength Variation.

The strength of a yarn depends not only upon the mean fibre strength of the cotton from which it is spun but also upon the variation of this property in the cotton. Hence it is of some interest to study what effect, if any, the insertion of twist in the fibres would have on the variability of their strength.

In Table VIII are given the probable errors of single observations expressed as fractions of the mean strength (*e* per cent.) The fourth column gives the differences between the values for the right-handed and left-handed twists, which are less than three times the probable error in all cases, showing that the direction of twisting has very little effect on the variability of strength.

Table VIII.

1	2 Twist	3 e%	4 Difference	5 Mean Twist	6 e%	7 $e_{25}-e_0$ (%)	8 $e_{50}-e_0$ (%)	9 $e_{100}-e_0$ (%)
Cambodia Co. 1.	0	37·4 ± 1·0		0	37·4 ± 1·0			
	25R	38·6 ± 1·1	0·1 ± 1·6	25	38·6 ± 0·8	1·2 ± 1·3		
	25L	38·7 ± 1·1						
	50R	39·9 ± 1·1	0·5 ± 1·6	50	39·6 ± 0·8		2·2 ± 1·3	
	50L	39·4 ± 1·1						
	100R	36·6 ± 1·0	2·2 ± 1·4	100	37·7 ± 0·7			0·3 ± 1·2
	100L	38·8 ± 1·0						
Verum 262.	0	34·7 ± 0·9		0	34·7 ± 0·9			
	25R	33·8 ± 0·9	1·4 ± 1·2	25	33·1 ± 0·6	−1·6 ± 1·1		
	25L	32·4 ± 0·8						
	50R	33·6 ± 0·8	1·5 ± 1·2	50	34·4 ± 0·6		−0·3 ± 1·1	
	50L	35·1 ± 0·9						
	100R	41·0 ± 1·1	2·8 ± 1·5	100	39·6 ± 0·7			4·9 ± 1·1
	100L	38·2 ± 1·0						
Banilla.	0	35·7 ± 0·9		0	35·7 ± 0·9			
	25R	34·9 ± 0·9	2·5 ± 1·3	25	36·2 ± 0·7	0·5 ± 1·1		
	25L	37·4 ± 1·0						
	50R	37·0 ± 1·0	0·9 ± 1·4	50	37·4 ± 0·7		1·7 ± 1·1	
	50L	37·9 ± 1·0						
	100R	40·6 ± 1·1	2·4 ± 1·6	100	41·8 ± 0·8			6·1 ± 1·2
	100L	43·0 ± 1·2						
Mollisoni.	0	31·1 ± 0·8		0	31·1 ± 0·8	0·9 ± 1·0		
	25R	31·3 ± 0·8	1·5 ± 1·1	25	32·0 ± 0·6			
	25L	32·8 ± 0·8						
	50R	33·8 ± 0·9	0·3 ± 1·3	50	33·6 ± 0·6		2·5 ± 1·0	
	50L	33·5 ± 0·9						
	100R	36·1 ± 1·0	3·1 ± 1·4	100	37·6 ± 0·7			6·5 ± 1·1
	100L	39·2 ± 1·1						
Aligarh A. 19	0	38·6 ± 1·0		0	38·6 ± 1·0			
	25R	38·2 ± 1·0	0·6 ± 1·4	25	37·9 ± 0·7	−0·7 ± 1·2		
	25L	37·6 ± 1·0						
	50R	37·9 ± 1·0	3·5 ± 1·5	50	39·6 ± 0·7		1·0 ± 1·2	
	50L	41·4 ± 1·1						
	100R	45·6 ± 1·3	1·1 ± 1·9	100	46·2 ± 1·0			7·7 ± 1·4
	100L	46·7 ± 1·4						

In view of the small effect, if any, caused by the direction of twist, the mean values for the two directions are taken and the values of e per cent. calculated from them are given in columns 5 and 6, while columns Nos. 7, 8 and 9 show the various differences between e_{25} and e_0, e_{50} and e_0, etc. These differences are small up to 50 turns, though there is a distinct tendency for e_{50} to be greater than e_0, showing that the variability of fibre strength is not affected appreciably in any of these cottons so long as medium twist is employed. Beyond this stage, however, the difference $e_{100}—e_0$ is small only for Cambodia Co. 1, but quite significant for the other cottons. Furthermore, it becomes greater as we go down the table, or in other words, as we consider the comparatively shorter cottons. Thus, with the insertion of a higher degree of twist the variability of fibre strength increases, and the increase is greater for the shorter than for the longer cottons. The insertion of higher twist thus not only makes the fibres weak but also less uniform in strength, and it is highly probable that the diminution in yarn strength, especially with short stapled cottons, on increasing the twist is related to these two factors.

III. Variation of Skewness and Type of Curve for Strength Values with different twists.

The frequency distributions, given in Table XVII, have been used to calculate skewness and to study the effect of twist on it. Skewness has been defined in different ways, some of which are:—

If M = Arithmetic mean

M_d = Median

(*a*) S $= 3(M - M_d)/\sigma$[19] where $\sigma =$ standard deviation.

(*b*) S $= (M - M_d)/c\sigma$ where $c = 0{\cdot}3309 - 0{\cdot}0846(M - M_d)^2/[\sigma^2 - 9(M - M_d)^2]$[20]

(*c*) S $= (E_1 - E_2)/M$[21] where E_1, E_2 are distances of the lower and upper quartiles from the arithmetic mean.

(*d*) S $= \mu_3/2\sigma^3$ (Gram-Charlier)[22]

(*e*) S $= \sqrt{\beta_1}(\beta_2 + 3)/2(5\beta_2 - 6\beta_1 - 9)$ where $\beta_1 = \mu_3^2/\mu_2^3$ and $\beta_2 = \mu_4/\mu_2^2$, μ_3 and μ_4 being the third and fourth moments about the mean (with Sheppard's corrections).

(*f*) S = As in (*e*) without Sheppard's corrections.

Since we know that fibre strength distribution is moderately asymmetrical, the formula (*a*) is suited to this work, besides offering ease in calculation. The formula (*e*) though somewhat more laborious in calculation is even better suited as it gives proper weight to the effect of individual values. Furthermore, it has the advantage that the probable error of skewness can be readily found from the published tables. It has not been considered necessary to apply Sheppard's correction to (*e*) as these are necessary for those curves which have high contacts at both ends, which is not the case in the present tests.

As regards the other formulae, (*b*) and (*c*) are likely to underestimate the abnormally high or low values while (*d*) is likely to overestimate them.

In view of these reasons, skewness was calculated for all cottons only according to formulae (*a*) and (*f*), while in the case of one cotton, namely, Banilla, all the formulae were used for purposes of comparison (Tables IX and X). It will be seen from Table IX that the order of skewness is the same regardless of the formula employed, with the exception of formulae (*d*) and (*c*) with 25 turns.

Table IX

Cotton	Twist	Formula (a)	Formula (f)	Formula (e)	Formula (b)	Formula (d)	Formula (c) × 10
Banilla...	0	0·31	0·42 ± 0·06	0·43	0·31	0·26	0·68
	25	0·29	0·41 ± 0·04	0·42	0·31	0·19	0·40
	50	0·42	0·61 ± 0·06	0·63	0·42	0·29	0·77
	100	0·69	1·11 ± 0·13	1·16	0·72	0·43	1·06

Alongside the values of skewness (formula *f*), the probable errors, as calculated from Pearson's "Tables for Statisticians and Biometricians"[24] are also given.

A study of Table X shows that in Banilla and Aligarh A.19 skewness has a tendency to increase with the twist, the increase being more marked with high than with low twist. A similar tendency is initially noticeable in Cambodia Co. 1, but here the skewness after increasing for $\theta=25$ remains approximately constant for higher twists. In Verum 262 and Mollisoni, on the other hand, the skewness has a tendency to fall, its value for $\theta=25$ and $\theta=50$ being less than for $\theta=0$, and then rises for $\theta=100$. Thus, all the cottons have this feature in common, that the skewness of their fibre strength distribution increases significantly at high twists, though at intermediate twists their behaviour may be different from one another. Excessive twisting of the fibre, therefore, not only increases the variability but also the asymmetry of the strength property of the fibre.

Table X. Values of Skewness and K_1.

$$K_1 = 2\beta_2 - 3\beta_1 - 6$$

Cotton	Twist	Formula (a)	Formula (f)	K_1.
Cambodia Co. 1 ...	0	0·44	0·45 ± 0·06	−0·13
	25	0·59	0·60 ± 0·05	−0·79
	50	0·50	0·56 ± 0·05	−0·80
	100	0·50	0·58 ± 0·05	−0·71
Verum 262	0	0·36	0·42 ± 0·06	−1·15
	25	0·38	0·33 ± 0·03	−1·08
	50	0·26	0·34 ± 0·04	−1·38
	100	0·48	0·65 ± 0·06	−1·49
Banilla	0	0·31	0·42 ± 0·06	−1·13
	25	0·29	0·41 ± 0·04	−1·44
	50	0·42	0·61 ± 0·06	−1·51
	100	0·69	1·11 ± 0·13	−1·89
Mollisoni	0	0·25	0·44 ± 0·06	−1·28
	25	0·23	0·32 ± 0·03	−0·84
	50	0·25	0·36 ± 0·03	−0·93
	100	0·56	0·73 ± 0·07	−1·46
Aligarh A. 19 ...	0	0·57	0·58 ± 0·07	−1·12
	25	0·56	0·62 ± 0·05	−1·32
	50	0·58	0·71 ± 0·06	−1·51
	100	0·79	1·14 ± 0·17*	−1·67

*** This value is rather uncertain, as it is obtained from the tables by extrapolation.**

Koshal and Turner[25] have shown that fibre strength values of Surat 1027 (full fibres) were best represented by a curve belonging to Pearson's[26] type I, viz.:—

$$Y = y_0(1 + x/a_1)^{m_1}(1 - x/a_2)^{m_2}$$

where a_1, m_1, a_2, m_2 and y_0 are constants. The same type of curve was obtained when 1 cm. lengths were broken (Navkal and Turner).[25a] For this the condition is that

$$K_2=\beta_1(\beta_2+3)^2/[4(4\beta_2-3\beta_1)(2\beta_2-3\beta_1-6)]$$

should be negative.[27] For all the frequency distributions in this paper $4\beta_2$ is greater than $3\beta_1$, and K_2 will be negative if K_1 or $2\beta_2-3\beta_1-6$ is negative. Since in order to calculate skewness, β_1 and β_2 were already known, it was easy to find K_1 for all distributions. The values obtained are given in Table X. The calculation of K_2 and the probable error of K_2 is rather laborious, but taking certain approximate values, it was estimated that K_2 was significant and negative in practically all cases. From a comparison of the values of K_1, it would appear that twisting has very little effect on the type of the curve which best represents fibre strength distribution.

IV. Change of Mean Length with Twist.

As has already been stated, the length of a fibre was read off in a telescope before and after the insertion of the twist. From these observations the percentage contraction in length could be calculated, and the mean values thus obtained for the different cottons and twists are given in Table XI which also shows the number of fibres tested for this purpose in each case.

Table XI

1 Cotton	2 Staple length	3 Twist θ	4 K_θ	5 Difference between R and L values (R-L)	6 Mean contraction (%)	7 No. tested
Cambodia Co. 1	0·89 in.	25R	0·38 ± 0·05	−0·04 ± 0·06	0·40 ± 0·03	120
		25L	0·42 ± 0·04			120
		50R	0·78 ± 0·06	−0·17 ± 0·09	0·86 ± 0·05	120
		50L	0·95 ± 0·07			120
		100R	4·45 ± 0·14	−0·65 ± 0·19 (*a*)	4·78 ± 0·10	300
		100L	5·10 ± 0·13			
Verum 262.	0·82 in.	25R	0·50 ± 0·05	+0·19 ± 0·06	0·40 ± 0·03	100
		25L	0·31 ± 0·04			100
		50R	1·32 ± 0·10	0·22 ± 0·16	1·21 ± 0·08	100
		50L	1·10 ± 0·12			100
		100R	6·71 ± 0·19	1·44 ± 0·26 (*b*)	5·99 ± 0·13	320
		100L	5·27 ± 0·18			310
Banilla.	0·76 in.	25R	0·46 ± 0·05	0·08 ± 0·08	0·42 ± 0·04	100
		25L	0·38 ± 0·06			100
		50R	1·14 ± 0·08	0·04 ± 0·12	1·12 ± 0·06	100
		50L	1·10 ± 0·08			100
		100R	6·66 ± 0·17	−0·22 ± 0·25	6·77 ± 0·13	280
		100L	6·88 ± 0·19			280
Mollisoni	0·69 in.	25R	0·54 ± 0·05	−0·13 ± 0·08	0·60 ± 0·04	150
		25L	0·67 ± 0·06			150
		50R	1·80 ± 0·10	0·33 ± 0·13	1·64 ± 0·07	150
		50L	1·47 ± 0·08			150
		100R	11·24 ± 0·28	1·40 ± 0·39 (*b*)	10·54 ± 0·17	299
		100L	9·84 ± 0·26			305
A 19	0·64 in.	25R	0·44 ± 0·05	0·13 ± 0·06	0·38 ± 0·03	100
		25L	0·31 ± 0·04			100
		50R	1·80 ± 0·09	0·40 ± 0·13	1·60 ± 0·06	220
		50L	1·40 ± 0·09			220
		100R	11·66 ± 0·26	0·88 ± 0·39	11·22 ± 0·19	320
		100L	10·78 ± 0·28			320

In column 5 of this table are given the mean differences between values for the right-handed and the left-handed twists together with the probable errors of the differences. It will be seen that in Cambodia Co. 1 the left-handed twist produced greater contraction than the right-handed twist for all the three degrees of twist, though the difference is significant only in the case of 100 turns (marked *a*). In the other four cottons the reverse is found to hold, i.e. the percentage contraction is on the whole greater with the right-handed than with the left-handed twist, though here again the difference is significant in two cases only, namely for Verum 262 and Mollisoni (marked *b*) each with 100 turns. We may, therefore, conclude that up to 50 turns the percentage contraction in length is nearly the same for the left- and the right-handed directions of twist, although in a majority of these cottons there is a tendency for the fibre to contract more with the right-handed than with the left-handed twist, this tendency being shown at high rather than at low twists. In view of the fact, however, that the differences between the values for the right-handed and the left-handed twist are generally insignificant, the mean values for the two directions of twist have been calculated and are given in column 6 of Table XI.

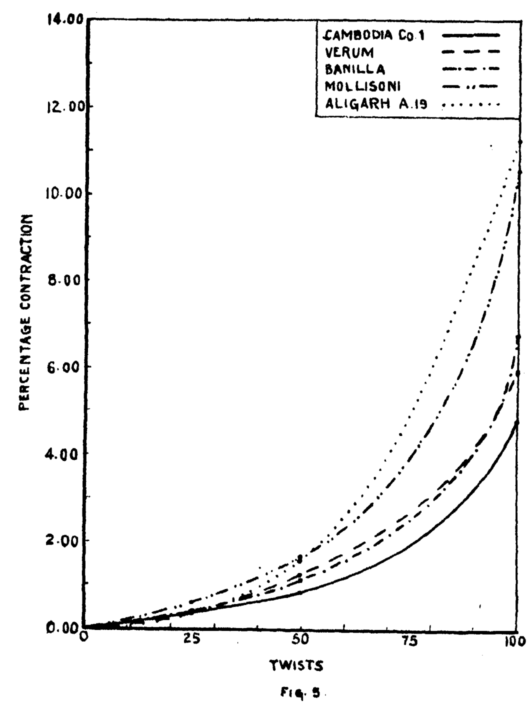


Fig. 5

These mean values have been plotted in Fig. 5. It will be seen that in all cases the percentage contraction increases very rapidly with twist, its value at 50 turns being two to four times that at 25 turns, while its value at 100 turns is four to seven times that at 50 turns. Furthermore, it will be seen that the percentage contraction is nearly the same for all cottons up to 25 turns, but that at 50 turns the individual response of the cottons begins to be noticeable, which becomes quite pronounced at 100 turns. This response takes the form of causing greater contraction with the shorter than with the relatively longer cottons, their order in this respect being roughly the same

as that of their mean fibre-length. To sum up, the fibres of all cottons contract on being twisted, the contraction increases rapidly with twist, and for medium and high twists is greater for the shorter than for the longer cottons.

This difference in the behaviour of the long and the short cottons may be explained as follows. As in a yarn, the twist will have a tendency to run into the thin places in the fibre. If r′ be the mean radius of these thin places, then r′ will depend upon r, the mean wall thickness of the whole fibre. But r is positively correlated to the fibre weight per inch, and since fibre weight per inch and mean length are negatively correlated, it follows that the percentage contraction in length will be greater in the shorter than in the longer cottons.

If the cotton fibre were even in ribbon width, we would expect that the contraction in length would be directly proportional to twist. In a non-uniform fibre, on the other hand, the contraction would be proportional to twist only in the initial stages, but the proportionality would be lost when on increasing the twist, it begins to run more and more into other places. That this actually happens will be seen from Table XII in which the differences K_{50}-$2K_{25}$, K_{100}-$2K_{50}$ and K_{100}-$4K_{25}$ are shown. If a proportionality between contraction and twist had existed for all values of twist, these differences would have been negligible in most cases. Actually, not only are they significant in most cases, but increase with the degree of twist and are greater for the shorter than for the longer cottons.

As regards the effect of *direction* of twist on the percentage contraction, it will be seen from Table XI that the differences between the percentage contraction for the two directions of twist are practically equal to zero in most cases. We thus conclude that so far as percentage contraction with twist is concerned, the direction of twist makes practically no difference and that in this respect all the cottons behave in a similar manner.

Table XII.

Cotton	K_{50}-$2K_{25}$	K_{100}-$2K_{50}$	K_{100}-$4K_{25}$
Cambodia Co. 1...	0·06 ±0·08	3·0 ±0·1	3·2 ±0·1
Verum 262 ...	0·41 ±0·10	3·6 ±0·2	4·4 ±0·2
Banilla	0·28 ±0·10	4·5 ±0·2	5·1 ±0·2
Mollisoni ...	0·43 ±0·10	7·3 ±0·2	8·1 ±0·2
Aligarh A. 19 ...	0·84 ±0·09	8·0 ±0·2	9·7 ±0·2

Table XIII.

Cotton.	Right-handed twist.			Left-handed twist.		
	$K_{50R}-K_{25R}$	$K_{100R}-K_{50R}$	$K_{100R}-K_{25R}$	$K_{50L}-K_{25L}$	$K_{100L}-K_{50L}$	$K_{100L}-K_{25L}$
Cambodia Co. 1	0·40 ±0·08	3·7 ±0·2	4·1 ±0·1	0·53 ±0·08	4·2 ±0·1	4·7 ±0·1
Verum 262	0·82 ±0·12	5·4 ±0·2	6·2 ±0·2	0·79 ±0·13	4·2 ±0·2	5·0 ±0·2
Banilla ...	0·68 ±0·09	5·5 ±0·2	6·2 ±0·2	0·72 ±0·10	5·8 ±0·2	6·5 ±0·2
Mollisoni ...	1·26 ±0·11	9·4 ±0·3	10·7 ±0·3	0·80 ±0·10	8·4 ±0·3	9·2 ±0·3
Aligarh A. 19	1·36 ±0·11	9·9 ±0·3	11·2 ±0·3	1·09 ±0·10	9·4 ±0·3	10·5 ±0·3

V. Effect of twist on the fibre length variation.

All cottons show a certain amount of variability in the length of the fibres. Tests at the Technological Laboratory have shown that the percentage variability in length is very nearly the same ($e\%=12$ to 15) for the

Table XIV.

Cotton	Direction of Twist	25 Twists				50 Twists				100 Twists			
		L	e_L	e_L (%)		L	e_L	e_L (%)		L	e_L	e_L (%)	
Cambodia Co. 1 ...	R	0·996	0·0052	0·52	0·5	0·992	0·0065	0·66	0·7	0·956	0·0249	2·60	2·5
	L	0·996	0·0049	0·49		0·990	0·0079	0·80		0·949	0·0228	2·40	
Banilla	R	0·995	0·0048	0·48	0·5	0·989	0·0083	0·84	0·8	0·933	0·0279	2·99	3·2
	L	0·996	0·0055	0·55		0·989	0·0085	0·86		0·931	0·0327	3·51	
Verum 262	R	0·995	0·0055	0·55	0·5	0·987	0·0097	0·98	1·1	0·933	0·0344	3·69	3·5
	L	0·997	0·0042	0·42		0·989	0·0122	1·23		0·947	0·0320	3·38	
Mollisoni	R	0·995	0·0056	0·56	0·6	0·982	0·0122	1·24	1·1	0·888	0·0485	5·46	5·2
	L	0·993	0·0069	0·69		0·985	0·0099	1·00		0·902	0·0448	4·97	
Aligarh A. 19	R	0·996	0·0048	0·48	0·4	0·982	0·0131	1·33	1·3	0·883	0·0458	5·19	5·4
	L	0·997	0·0034	0·34		0·986	0·0132	1·34		0·892	0·0502	5·63	

five cottons considered here. Balls,[28] in this connection, observes: " Usual relative variation of hair length is similar throughout the genus." If, however, the lengths of the individual fibres are modified, to a varying extent, by some such extraneous factors as twist, it is possible that the length variability may be altered and that the alteration may be different for the different cottons. If K be the percentage contraction due to twisting in fibres 1 cm. long, then their average length after the insertion of the twist is given by

$$L = 1 - K/100.$$

If their length variability is expressed in terms of the percentage probable error, then

$$e_L\,(\%) = e_L \times 100/L$$

$$\text{Now } e_L = e_K$$

$$\therefore\ e_L\,(\%) = 100e_K/(1 - K/100)$$

The values of e_L (%) calculated as above for different cottons and twists are given in Table XIV.

Several interesting points emerge from a study of this table. It will be seen, in the first place, that the contribution of twist to the length variability is practically the same for all cottons up to 25 turns and is negligible, i.e. up to this limit the cottons behave normally as if the fibres are untwisted. Beyond this stage, however, the length variability increases with the twist, and the increase is greater for the shorter than for the relatively longer cottons. Thus, as more twist is inserted in the fibres, the " spread " of the values of their length increases, the effect being more marked with the shorter than with the longer Indian cottons.

We have seen above that the fibres suffer contraction in length on being twisted and that the percentage contraction is greater for the short than for the relatively long Indian cottons. Now, it is highly probable that this phenomenon of variable contraction holds not only as between different cottons but also between short and long fibres of the same cottons, though to a lesser extent. If this view is correct, then it follows that the short fibres in a cotton will contract more than the long ones, thereby increasing the length variability of the cotton with high twists. Furthermore, as cottons with a low mean fibre length will contain more fibres of a low length grade (say ½ in.), the modification in the length variability brought about by twist will be greater for the short than for the long cottons. We thus see that the effect of twist on the length variability arises out of the variable degrees of contraction of the long and the short fibres, which in its turn is related to the presence of the thick and thin places in the fibres.

VI. Relationship between fibre strength and percentage contraction.

Since the tensile strength (W) and the percentage contraction (K) for numerous fibres of each cotton are known, their values may be utilised for calculating the correlation coefficients between these two properties. These are shown in Table XV. In view of the fact that at least 300 fibres were tested at 100 turns, the correlation coefficients, r_{KW}, for 100 turns are given for all cottons, but as a smaller number of fibres were tested for 25 and 50 turns, the values of the correlation coefficients for these two twists are given only for one cotton, namely Mollisoni.

Table XV.
Correlation coefficients between K and W.

Cotton	Twists	r_{KW}	Significance
Mollisoni	25R	$-0{\cdot}14 \pm 0{\cdot}05$	Insignificant
„	25L	$-0{\cdot}17 \pm 0{\cdot}05$	Just significant
„	50R	$-0{\cdot}14 \pm 0{\cdot}05$	Insignificant
„	50L	$-0{\cdot}09 \pm 0{\cdot}05$	Insignificant
„	100R	$-0{\cdot}16 \pm 0{\cdot}04$	Just significant
„	100L	$-0{\cdot}10 \pm 0{\cdot}04$	Insignificant
Cambodia Co. 1 ...	100R	$0{\cdot}09 \pm 0{\cdot}04$	Insignificant
„	100L	$0{\cdot}07 \pm 0{\cdot}04$	Insignificant
Verum 262	100R	$-0{\cdot}19 \pm 0{\cdot}04$	Significant
„	100L	$-0{\cdot}07 \pm 0{\cdot}04$	Insignificant
Banilla	100R	$-0{\cdot}17 \pm 0{\cdot}04$	Significant
„	100L	$-0{\cdot}10 \pm 0{\cdot}04$	Insignificant
Aligarh A. 19 ...	100R	$-0{\cdot}07 \pm 0{\cdot}04$	Insignificant
„	100L	$-0{\cdot}09 \pm 0{\cdot}04$	Insignificant

If the twist inserted in a fibre runs into its thin places the percentage contraction (K) will be proportional to the number and diameter of these places. If the twisted fibres, on tension being applied, break most frequently at *these* thin places, one would expect that the tensile strength (W) should bear some relationship to percentage contraction. Actually, as we see from Table XV the correlation coefficients are insignificant in most cases, and wherever they are not so, they are on the border line of significance.

This absence of any marked correlation, contrary to expectation, deserves to be considered in some detail. In developing the foregoing argument we assumed that the twist ran into the thin places of the fibre, which, on tension being applied, broke at one of these places. The latter assumption is supported by the observations of Miss Clegg,[29] who found that about 60 per cent. of the fibres ruptured at their thin places. It is, however, possible that, as in a yarn, the twist may have the effect of strengthening the weak places, and, consequently, the fibre rupture may not be restricted, for the most part, to the narrow sections where the contraction takes place, but may be distributed more or less uniformly over the whole length of the fibre. The fibre rupture would then take place at the cross-sections where the internal forces between the micellar chains are least, regardless of the diameter at these sections. Furthermore, it is possible that a certain fraction of the fibres in a cotton may have received injuries either in the ginning process or through the agency of the cellulose-destroying micro-organisms. These injuries, which may be seen under the microscope by staining the fibres with Congo Red dye, will not be restricted to the thin places, but will be distributed more or less uniformly over the surface of the fibre. Now, it is highly likely that twist, especially of a high degree, will have the effect of further weakening the already damaged parts, and, therefore, the rupture may take place just as frequently at the thick as at the comparatively thin places.

VII. Part played by Twist in the Spinning Process.

(1) *Variation of Yarn Strength with twist.* In the various stages leading up to the preparation of a yarn, the insertion of a certain amount of twist is necessary. In the roving stage, just enough twist is inserted to hold the

fibres together, while in the spinning process, the twist also serves the purpose of imparting additional strength. The number of turns per inch (T) in a yarn is generally expressed by the formula

$$T = t\sqrt{c}$$

where t is the twist constant and c the count to which the yarn has been spun.

The variation in yarn strength with twist has been studied by a number of workers, amongst whom may be mentioned English[30], Turner and his collaborators,[31, 32] Morton,[33] Balls,[34] Oxley[35] and Mercier and Schoffstall.[36] It may be mentioned that yarn strength may be expressed either as lea breaking strength or single thread strength, or alternatively, the ballistic work of rupture of a lea or a single thread may be used. The following general conclusions may be drawn from a study of the works of the above-named authors:—

(i) As the twist constant is raised from 3·5 to 5·0

(*a*) the lea strength increases, reaches a maximum and then falls. This maximum may be absent for short and coarse cottons.

(*b*) the single thread strength also increases with twist ; but the maximum may not always be reached within the limit of $t=5$, especially for the coarse cottons ;*

(*c*) the ballistic count-work product also increases with twist, but no maximum is reached.

(ii) The values of the twist at which these maxima are reached are generally lower for the long staple than for the medium staple cottons and higher for the short staple varieties.

(iii) In a given range of twist, the strength as indicated by any of the methods mentioned above increases more rapidly for the medium than for the long staple cottons, while the short staple varieties appear to derive the maximum benefit from any increase in twist.

We will now summarise the effect of twist on the strength of a fibre which has been discussed in detail in the preceding pages. We may for this purpose refer to the curves in Fig. 4. We find that—

(1) As the twist in a fibre is increased, its strength increases, rapidly at first and more slowly afterwards, reaches a maximum and then falls. The type of the twist-strength curve for a fibre is very similar to the twist-strength curve for a typical yarn for lea or single thread strength.

(2) For a given increase in twist, the fibres of the shorter cottons show a greater increase in strength than those of the comparatively long staple cottons.

(3) The maxima for fibre strength are much higher than those for single thread strength, which, in their turn are generally higher than those for lea strength, no fibre showing its maximum strength until at least 40 to 60 turns per inch have been inserted in it.

Thus, broadly speaking, there is a close parallelism between the behaviour of a yarn and a fibre when twist is inserted in them.

(2) *Lack of correlation between the yarn strength and fibre strength.* If this parallelism is considered along with the fact that, like its component fibres, the yarn increases in strength with humidity or loses its strength with chemical or bacterial damage or under prolonged exposure to light, we are justified in expecting a high degree of association between fibre strength and

* It is remarkable that even in the case of worsted yarns, the maximum lies somewhere in this region as shown by Stanbury and Byerley.[37]

yarn strength. In actual practice, this expectation is not fully realised. Turner [38] obtained a small negative correlation coefficient between count-strength product (C.S.P.) and the fibre strength, while the correlation coefficient between C.S.P. and the intrinsic strength (fibre strength ÷ fibre weight per inch) was found to be zero. Burd[39], Clegg[40] and Morton[41], have all obtained similar results. Only Barritt,[42] working with 14 samples of Egyptian varieties spun into 140's, found that the correlation coefficient between fibre and yarn strength was fairly high. Recent values obtained in this laboratory give a moderately high correlation between the intrinsic strength and the highest standard warp counts for the standard Indian cottons, though it is definitely less than the correlation coefficient between highest standard warp counts on one hand and either the mean fibre length or the mean fibre weight per unit length of the cotton on the other.

(3) *Factors responsible for the lack of correlation between the two properties.* The question, therefore, arises: What are the reasons for this lack of a satisfactory relationship between fibre strength and yarn strength? This question has been considered in some detail by Turner[43] and only the more important reasons will be stated here.

In yarn tests the fibres are broken in groups and the group strength may be quite different from the sum of the strengths of the individual fibres, especially if the latter are bound together by twist. Furthermore, if due allowance is made for the number of fibres in a cross-section of the yarn, the rate of loading of the fibres constituting the yarn is different from that for a single fibre in a fibre test. Now, it is well known that within certain limits the breaking strength of a fibre depends upon the rate of loading, the faster loading giving a higher strength. Again, it should be remembered that fibre strength depends to a large extent upon the length of the test piece as shown by Clegg[44] and Balls.[45] In routine testing, fibres 1 cm. long are tested for strength, while in the yarn the fibres affected in yarn ruptures are generally less than one centimetre in length. We must also remember that in a yarn the fibres lie spirally around the yarn axis and, therefore, only a certain component, depending upon the twist, of the force applied is effective in breaking them. Finally, since it is highly probable that the properties of the fibres are modified to some extent by twist, we should take into account this factor in assessing yarn strength in relation to its component fibres.

(4) *Change of fibre properties with twist.* We will now examine the last point in its various aspects, confining ourselves to such changes in fibre-properties as occur up to a limit of about 35 turns per inch or 15 turns per cm. This limit is chosen, because no Indian cotton spun for warp purposes is given a higher twist. From the earlier sections of this paper it will be remembered that so far as length and its variation are concerned twist does not have a favourable effect from the beginning. The same is true of strength variation. However, a reference to Tables VIII, XI and XIV will show that the adverse effect of these three factors is practically negligible in the region under consideration. On the other hand, as shown in Table X, the skewness improves with twist in some cases. But more important than this is the fact, shown in Table IV, that the strength of the fibre increases with twist, while from the work of Peirce[46] it is highly probable that an improvement also results in the plasticity of the fibre. Thus, on the whole, twist up to 15 turns per cm. should have a beneficial effect upon the fibre by giving it greater strength and plasticity, while leaving the other properties

practically unaffected. We shall now consider the effect of twist on fibre strength, and its relation to yarn strength in some detail.

(5) *Change of fibre strength with twist and its influence upon yarn strength.* It has been shown above that fibre strength, like yarn strength, increases with twist until a maximum is reached, and that the rate of increase of fibre strength is less for the longer than for the shorter cottons. The parallelism between the behaviour of the fibre and the yarn in regard to the effect of twist on their strength, however, does not extend much further. When we compare the magnitudes of increase in strength with twist, we observe large differences between the behaviour of the fibre and the yarn. In Table XVIA* we have given some results showing the percentage increase in lea and single thread strength of yarn when the twist constant is increased from 4·0 to 4·25 (3·5 to 3·75 for African cottons) from which the percentage increase C for a change of 1 turn per inch has been calculated and given in column (vi) of the table. In Table XVIB the value of C (percentage increase in strength for an increase of 1 turn per inch) is given for fibres of the cottons tested in the course of this investigation.

Table XVIA.

t = Twist Constant.

A = Percentage increase in strength when t is changed from 4.0 to 4.25 (3.5 to 3.75 for African Cottons).

B = Increase in the number of turns per inch for above-mentioned change in t.

C = A/B = Percentage increase in strength for a change of 1 turn per inch.

(i) Cotton	(ii) Test	(iii) Count	(iv) A	(v) B	(vi) C = A/B
Oomra	Lea	10-12	33	0·83	40
Mollisoni	,,	6-8	35	0·66	53
P.A. 4F	,,	26	1·0	1·27	0·8
Cambodia Co. 1	,,	20-48	1·1	1·46	0·8
Africans (average)	,,	40	4·1	1·58	2·6
Oomra	Single Thread	10-12	23	0·83	28
Mollisoni	,,	6-8	20	0·66	30
P.A. 4F	,,	26	8·1	1·27	6·4
Cambodia Co. 1	,,	20-48	4·5	1·46	3·1
Africans (average)	,,	40	5·1	1·58	3·2

Table XVIB.

C = Percentage change in fibre strength, per unit increase in the twist per inch, when the turns per inch are changed from 0 to 30.

Cotton.	C.
A. 19	0·10
Mollisoni	0·12
Verum 262 ...	0·14
Banilla	0·01
Co. 1	0·04

We notice that for the lea test whereas C is about 1-3 per cent. for the medium counts (26's-40's) spun from the better quality, it may be as high as 40-50 per cent. for the coarse counts (6's-12's) spun from the

* The material in Table XVIA is taken from the data collected at the Technological Laboratory for Indian and African cottons.

lower quality cottons. The values of C for single thread test, though somewhat different from those obtained for the lea test, are however of the same order of magnitude, being 3-6 per cent. for the medium counts and about 30 per cent. for the coarser ones. As against these comparatively large changes in yarn strength, we notice that for the same increase in twist in the same range the fibre strength increases only by 0·01-0·04 per cent. for the better quality cottons and by 0·1-0·14 per cent. for the shorter cottons. Thus, although the difference in the two classes of cottons in their reaction to twist is still maintained in the fibre as in the yarn, the percentage increase in fibre strength is much smaller than that in yarn strength, the former being only about a hundredth part of the latter. We should also remember that we are considering the effects in the neighbourhood of the twist constant 4, where the rate of change of yarn strength with twist is relatively small. If we take into consideration the initial stages of inserting twist in a yarn, the contribution of any increase in fibre strength would be even less. Hence, we conclude that when twist is inserted in yarn, the strength of its component fibres is likely to increase by a small amount, but that this increase in fibre strength can account only for a very small fraction of the increase which takes place in yarn strength, the rest being due to other factors.

VIII. Variation of Fibre Strength with Twist in relation to Fibre Structure.

In this section we will first describe briefly the structure of the cotton fibre and will then make an attempt to explain, on the basis of this structure, the main results obtained by us. We shall adopt the molecular chain theory of fibre structure which in our opinion better fits the experimental evidence, derived from chemical analysis and X-ray investigation, than any other theory.[47] According to the postulates of this theory the cotton fibre is ultimately made up of β glucose residues, which are linked together by primary valencies to form long molecular chains in which the glucose rings are faced alternately in opposite directions. A number of these molecular chains, which are held together by secondary valency forces, constitute micelles, which are of varying size and varying degrees of perfection, but which have this common feature that their length far exceeds their breadth. In the case of cotton fibre these micelles are arranged to lie more or less parallel to one another along lines which wind spirally round the fibre, with here and there regions in which the chain arrangement attains crystalline regularity. Superposed upon this fundamental structure of the cotton fibre are its natural twists or convolutions, which change direction at irregular intervals. Finally, the surface of the fibre is interspersed with a number of pits, fissures and cracks about which our present-day knowledge has been summarised by Osborne.[48]

We will now recapitulate the main results of our experiments. We found that, except in the case of Cambodia Co. 1, insertion of twist in the fibre at first increased its strength until it reached a maximum value after which, with further twisting of the fibre, the strength steadily diminished. We further saw that, as the twist was increased, the diminution in strength was accompanied by greater variability and higher skewness of the strength distribution. Furthermore, we noticed a slight tendency for the strength values to be lower with the right-handed than with the left-handed twist. In the case of Cambodia cotton it is highly probable that, if more twist had been inserted, its fibre strength would have diminished as in the case

of other cottons after reaching a certain maximum. We may, therefore, conclude that the foregoing observations hold for all cottons, which, however, differ from one another in respect of the rate of increase or decrease of strength with twist, the point at which the maximum strength is attained, the magnitude of change in skewness and variability, etc.

In the unstretched state when no tension is applied to the fibre the molecular chains or micelles are generally orientated in such a way as to make a certain angle with the fibre axis. This angle is by no means a constant quantity, but may vary at different points along the length of the fibre. When the fibre is stretched, these chains tend to place themselves along the axis of the fibre as shown by Astbury.[49] The angle of inclination becomes progressively less as the tension on the fibre is increased. A part of the force applied, therefore, is spent in straightening out the micelles so that they may lie more nearly parallel to the fibre axis. The greater the initial inclination of the micelles to the axis, the greater will be the force required to straighten them out. However, it is possible that before these chains are made to lie even nearly parallel to the axis the fibre may break under the action of the stretching force. It is highly probable that in most cases the rupture of the fibre, at least in the very initial stages, is not due to the breaking asunder of the molecular chains since it has been calculated that the force required for this purpose is greater than the average strength of the fibre. The process, in all probability, begins by the chains slipping over one another, and either it is continued right to the end, or up to a point when the force on the few remaining chains, which still hold out, is sufficient to break them, the final result in both cases being the rupture of the fibre.

When twist is inserted in the fibre, it will have the effect of (1) increasing the inclination of the micelles to the fibre axis and (2) of increasing the lateral pressure exerted by the micelles over one another as a result of which they are held more firmly together and (3) of improving the alignment of the micelles along the lines of force of twist as a result of which their area of contact increases, with consequent increase in the force holding the chains together, as shown by Mark.[50] These effects will increase with the amount of twist inserted in it. If the fibre is now stretched by applying tension to it, more force will be required to cause the micelles to lie nearly parallel to the fibre axis until the point is reached at which the fibre rupture takes place in the manner indicated above. When this point is reached and the molecular chains commence to glide over one another, the force required to separate them completely by overcoming their mutual cohesion will be greater. These effects will increase with the amount of twist inserted and, therefore on the molecular chain theory we should expect that the strength of the fibres would increase, at least up to a limit, with the amount of the twist inserted in them. This is precisely what is observed by us.

If the twist produced only these three effects, namely, increasing the average inclination of the micelles to the fibre axis, increasing the lateral pressure exerted by them over one another, and improving the alignment of the micelles, we should expect that fibre-strength would go on increasing indefinitely with increase in twist. But in addition to these three effects, the twist would produce other effects as well which may not be favourable to fibre strength and which we shall now consider. In the first place, owing to the elongation of the spiral lines brought about by the twist, the

longitudinal tension on the micelles would increase. Since the chains would now lie in a state of tension, they would be inclined to snap by the application of a smaller external force. Secondly, the shearing effect of the twist would tend to enlarge any fissures, cracks or pits on the surface of the fibre to which a reference has been made above. These enlarged fissures would also have the effect of weakening the fibre which would now be unable to withstand the same breaking force as it would have normally done. It stands to reason that both these effects, namely the longitudinal tension in the micelles and the enlargement of the fissures would be negligible at low twists, but would steadily increase as more and more twist is inserted in the fibre, until at high twists they would be quite large. As this state of affairs is being reached smaller and smaller external force would be required to break the fibre.

We see, therefore, that as a fibre is twisted and the amount of twist is gradually increased, two opposing sets of factors are brought into play, one of which tends to increase its strength, while the other tends to decrease it. The effect of the former predominates at lower twists as a result of which fibre strength rises, while that of the latter begins to assert itself at moderately high twists ; consequently the fibre strength reaches a maximum value and then declines as more and more twist is inserted in it. The molecular chain theory of the structure of the fibre, taken in conjunction with known facts regarding the surface appearance of the fibre, is therefore capable of explaining, in a general way, its behaviour under the action of progressively increasing twist.

We have seen that the cottons exhibit differential response to twist in respect of the rate of increase of fibre strength with twist and the point at which the maximum strength is attained. In the short staple cottons, as a rule, the fibre strength rises more rapidly with the twist than in the comparatively longer cottons and the point of maximum strength is reached earlier. If we were to assume that the micelles in the fibres of the short staple cottons are inclined to the axis at a greater average angle than in the fibres of the long staple cottons, both these observed facts would be readily explained. For, on this assumption, the insertion of a small amount of twist would result in the micelles in the short staple cotton fibres making a fairly large angle with the axis, while such would not be the case in the fibres of the long staple cottons in which the initial inclination was small. It can be easily shown that if a force f acts upon the micellar chain, the tension along the fibre axis (F) is $f \sec \theta$ where θ is the angle made by the tangent to the spiral line with the direction of the fibre axis. Consequently, after the insertion of the twist, since θ on the average is greater in the short staple cottons, the external force required to make the micelles lie nearly parallel to the fibre axis would be greater in these than in the long staple cottons. Furthermore, since $dF/d\theta = f \tan\theta \sec\theta$ the former cottons would exhibit a greater rate of increase in fibre-strength with twist than the latter if f is constant. Again, owing to the greater inclination of the spiral lines, the longitudinal tension on the molecular chains produced by the twist after it exceeded a certain value would be greater in the fibres in which the micelles are inclined at larger angles to the fibre axis, therefore, in these cottons the point of maximum strength would be reached sooner than in those in which the micelles make smaller angles with the fibre axis. We thus see that the differential response of short staple and long staple cotton fibres to twist can be explained by assuming that in the former the spiral lines

along which the micelles lie make, on the whole, larger angles with the fibre axis than in the latter. We must admit that we have no direct experimental evidence for this assumption ; we offer it only as an indirect inference from the observed facts which it explains rather well.

We have referred, in the foregoing paragraphs, to the fissures and cracks in the surface of the fibre and the role played by them in accounting for the observed decrease in fibre strength after the twist has attained a certain value. It is highly probable that the number and general contour of these fissures would vary appreciably from fibre to fibre. When the fibres are twisted, the effect of twist on these fissures would depend upon their number and contour, and would, therefore, be different for the different fibres, even in the same cotton. Furthermore, the manner in which the micelles would be orientated in each fibre i.e. the inclination to fibre axis at different points, the frequency of reversals of direction of spiral lines, etc., would also be different in the different fibres, and it is possible that the insertion of twist may accentuate these effects. Thus, as a result of the working of both these factors, which have their origin in the secondary differences existing betwen individual fibres, we may reasonably expect that the spread of the strength values and the skewness of the distribution curve would increase somewhat with twist. This is what we have actually observed in our experiments.

The micelles are sub-microscopic structures whose existence has been definitely established by X-ray analysis, but there is some evidence to show that these are grouped together in thin long bundles called fibrillae. As stated above, the spirals along which these lie in a fibre reverse directions at irregular intervals, being clockwise in one region, anti-clockwise in the next and so on. According to Balls,[51] under certain conditions the reversals in the direction of the fibrillae correspond to those of convolutions, though it may not always be the case. If the spirals wound in one direction just as often as in the other, the effect of direction of twist would be negligible ; if, on the other hand, the spirals wound in one direction—clockwise or anti-clockwise—more often than in the other, the effect of twist in this particular direction would be greater than in the other. This is exactly what is observed by us, and we infer from the results of our experiments that, at least in the cottons examined by us, the reversal of the spiral along which the fibrillae lie is probably more frequent in the left-handed than in the right-handed direction. Again we repeat that this should merely be looked upon as an inference drawn by us to account for a certain observed phenomenon, but that more work is necessary before we can either accept it definitely or offer an alternative explanation.

ACKNOWLEDGMENT.

A part of the investigation was carried out by one of us under Dr. A. J. Turner to whom our thanks are due not only for his guidance but also for kindly going through the proofs of this Bulletin.

Received 21/6/1937

REFERENCES.

1 Monie, H. "The Cotton Fibre," Manchester, 1904, p. 25.
2 Bowman, F. H. "Structure of the Cotton Fibre," London, 1908, pp. 364-6.
3 Turner, A. J. "The Foundations of Yarn Strength and Extension," Parts I and II, *I.C.C.C. Tech. Bull.*, Series B, No. 1, 1928, or *J. Text. Inst.*, 1928, **19**, T286.
4 Clegg, G. G. "The breaking of yarns and single cotton hairs," *J. Text. Inst.*, 1926, **17**, T595.
5 Turner, A. J. As Ref. 3, pp. 12-13.

[6] Turner, A. J. and Venkataraman, V. "The Foundations of Yarn Strength and Extension," Part V, *I.C.C.C. Tech. Bull.*, Series B, No. 17, 1933, p. 18, or *J. Text. Inst.*, 1934, **25**, T1.
[7] Gulati, A. N. and Turner, A. J. "The Foundations of Yarn Strength and Yarn Extension," Part IV, *I.C.C.C. Tech. Bull.*, Series B, No. 9, 1930, or *J. Text. Inst.*, 1930, **21**, T561.
[8] Barratt, T. "Measurement of breaking stresses, extensibilities and elasticities of single fibres of cotton," *J. Text. Inst.*, 1922, **13**, T17.
[9] Navkal, H. and Sen, K. R. "A comparison of some methods of testing breaking strength of single cotton fibres," *I.C.C.C. Tech. Bull.*, Series B, No. 5, or *J. Text. Inst.*, 1930, **21**, T267.
[10] Schwendinger, P. "Deforden testing apparatus, source of error," *B.C.I.R.A.*, 1935, XV, p. 366.
[11] Barratt, T. As Ref. 8, p. 27.
[12] Collins, G. E. "The extensibility of cotton hairs," *J. Text. Inst.*, 1930, **21**, T317.
[13] Mann, J. C. "The Influence of humidity on the elastic properties of cotton. On the breaking load at 20° C., *J. Text. Inst.*, 1927, **18**, T253.
[14a] Work done at the Technological Laboratory (unpublished).
[14] Wilcomm. Quoted by Mann, Ref. 13.
[15] Urquhart, A. R. and Williams, A. M. "The moisture relations of cotton" (Effect of temperature), *J. Text. Inst.*, 1924, **15**, T569.
[16] Navkal, H. and Sen, K. R. As Ref. 9, p. 9.
[17] Roehrich, O. "Twisting of cotton fibres," *Text. Res.*, Vol. V, p. 254.
[18] Clegg, G. G. and Harland, S. C. "A Study of convolutions in the cotton hairs," *J. Text. Inst.*, 1924, **15**, T21.
[19] Mills, F. C. "Statistical Methods," London, 1925, p. 167.
[20] Kelley, T. L. "Statistical Method," Cambridge (U.S.A.), 1923, p. 61.
[21] Koshal, R. S. and Turner, A. J. "Studies in the sampling of cotton for the determination of fibre properties," I and II, *I.C.C.C. Tech. Bull.*, Series B, No. 6, 1930, p. 32, or *J. Text. Inst.*, 1930, **21**, T325.
[22] Rietz, H. L. "Mathematical Statistics," 1927, p. 69.
[23] Jones, D. C. "A first course in Statistics," London, 1924, p. 205.
[24] Pearson, Karl. "Tables for Statisticians and Biometricians," Cambridge University Press, 1924, p. 67-77.
[25a] Work done at the Technological Laboratory (unpublished).
[25] Koshal, R. S. and Turner, A. J. As Ref. 21, p. 36-37.
[26] Elderton, W. P. "Frequency Curves and Correlation," London, 1927, p. 54.
[27] Pearson, Karl. "Tables for Statisticians and Biometricians," Cambridge University Press, 1924, pp. 46, 47.
[28] Balls, W. L. "Studies of quality in cotton," 1928, Macmillan & Co., London, p. 47.
[29] Clegg, G. G. As Ref. 4, T.600.
[30] English, W. "The relation between the breaking strength of cotton yarns and twist at the place of breaking," *J. Text. Inst.*, 1924, **15**, T388.
[31] Gulati, A. N. and Turner, A. J. As Ref. 7.
[32] Richardson, R. P. and Turner, A. J. "Limit Spinning Tests on Cambodia and Mollisoni Cottons," *I.C.C.C. Tech. Bull.*, Series A, No. 17, 1930, p. 9 and 10.
[33] Morton, W. E. "The spinning value of raw cotton," *J. Text. Inst.*, 1930, **21**, T205-17.
[34] Balls, W. L. As Ref. 28, p. 218-19.
[35] Oxley, A. E. "The regularity of single yarns and its relation to tensile strength and twist," *J. Text. Inst.*, 1922, **13**, T91.
[36] Mercier, A. A. and Schoffstall, C. W. "Effect of twist on cotton yarns," *Bureau of Standards Journal of Research*, 1928, p. 733.
[37] Stanbury, G. R. and Byerley, W. G. "The relation between the strength, count and twist of single worsted yarn," *J. Text. Inst.*, 1934, **25**, p. T295.
[38] Turner, A. J. As Ref. 3, pp. 12-13.
[39] Burd, L. H. "Spinning Tests of St. Vincent Sea Island Cotton," Kingstown, 1925.
[40] Clegg, G. G. As Ref. 4, p. 592.
[41] Morton, W. E. "The spinning value of raw cotton," *J. Text. Inst.*, 1930, **21**, p. 205-17.
[42] Barritt, N. W. "The intrinsic strength of cotton," *J. Text. Inst.*, 1929, **20**, T71.
[43] Turner, A. J. As Ref. 3, p. 14.
[44] Clegg, G. G. As Ref. 4, T599.
[45] Balls, W. L. As Ref. 28, p. 234-9.
[46] Peirce, F. T. "The plasticity of cotton and other materials," *J. Text. Inst.*, 1923, **14**, T390.
[47] Davidson, G. F. "The molecular structure of cellulose," *J. Text. Inst.*, 1936, **22**, p. 144.
[48] Osborne, G. G. "Micro analysis of textile fibres," *Text. Res.*, Vol. V, p. 275.
[49] Astbury, W. T. "The fundamentals of fibre structure," Oxford University Press, 1933, pp. 88-89.
[50] Mark. *Trans. Faraday Soc.*, 1933 **29**, 9.
[51] Balls, W. L. As Ref. 28, p. 20.

APPENDIX I.

Table XVII. Frequency Distribution for W.

Gms. (ω −0·05)	Co. 1				Verum				Banilla				Mollisoni				A. 19			
	0	25	50	100	0	25	50	100	0	25	50	100	0	25	50	100	0	25	50	100
0	7	13	16	10	3	11	10	18	1	9	8	8	0	4	2	5	3	9	15	22
1	46	97	101	87	21	36	45	66	26	51	51	69	11	34	40	57	33	47	55	109
2	79	178	162	152	68	81	90	154	45	85	96	156	43	73	79	188	52	116	125	230
3	96	199	170	197	49	114	94	136	57	107	131	148	69	104	116	153	77	143	139	184
4	83	159	153	179	89	144	157	132	58	105	129	132	65	117	136	142	75	144	131	152
5	63	112	126	128	57	161	109	126	57	110	105	109	67	139	107	120	55	118	137	94
6	57	94	93	102	63	125	108	102	51	102	100	88	75	144	112	89	44	98	76	61
7	29	55	58	53	47	100	115	76	50	98	95	70	47	116	115	88	48	80	78	52
8	19	42	51	45	53	100	90	85	53	80	93	69	48	86	101	68	47	89	96	46
9	10	20	33	26	36	70	83	47	32	76	50	42	31	65	58	37	28	58	56	28
10	3	16	20	15	21	48	73	54	34	62	51	40	18	51	69	29	21	51	45	19
11	4	11	13	10	10	43	41	33	16	54	40	30	16	28	31	16	17	38	39	20
12	2	3	1	3	9	13	25	14	15	51	37	20	5	22	18	6	7	21	20	15
13	1	0	2	5	5	7	13	7	5	11	14	17	4	10	10	3	3	12	8	3
14	1	0	1	1	1	6	4	4	3	5	8	7	1	3	7	3	7	10	23	3
15	0	0	1	0	0	1	1	5	5	3	4	9	—	4	2	1	2	1	2	3
16	0	1	1	—	1	—	2	1	1	5	3	2	—	—	2	—	0	2	2	0
17	—	—	—	—	—	—	—	—	1	2	1	—	—	—	0	—	2	2	2	2
18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	0	1	—	—
Total ...	500	1000	1002	1013	533	1060	1060	1060	510	1016	1016	1016	500	1000	1006	1005	521	1040	1049	1043
Mean (calculated)	4·15	4·09	4·31	4·28	5·53	5·80	6·04	5·23	6·10	6·28	5·90	5·27	5·70	5·97	6·00	4·75	5·53	5·66	5·62	4·17

(*a*) Figures for the right-handed and the left-handed twists have been combined.

(*b*) The means given are the calculated ones. They will differ somewhat from the *actual* means given in the body of the paper. Only in two cases is this difference greater than 0·02 gms., i.e., ½ per cent.

Correspondence

A REVIEW OF TESTING INSTRUMENTS AND AN IMPROVED RECORDING FIBRE TESTER

To the Editor,

Sir,

As one of the authors of the above paper, which appeared in the May issue of the *Journal,* may I express my appreciation of the comments made by Dr. Krais in his letter of June 17th.

With one of his points, that a testing machine cannot be free from the effects of friction and yet retain simplicity in construction and operation, the authors can hardly agree. Dr. Krais's skill and experience have provided the ingenious Krais-Keyl apparatus in which frictional effects are negligible.

In the Osumi-Kato instrument friction between the pen and the paper and that of the moving parts do not affect the indication of the tensile strength of the test piece. Friction can be ignored so long as its effects are under the control of the operator.

Large magnification of extension is generally a difficult problem. This, however, is not the case with the Osumi-Kato instrument, with which elongation may be magnified 100 times, using a relatively low grade magnoscope. The Improved Recording Fibre-Tester is highly sensitive and may be regarded as free from friction. It is simple to make and easy to use.

(Signed) G. OSUMI.

Tokyo University of Engineering,
11/10/1937.

YARN STRENGTH OF EGYPTIAN MIXINGS

To the Editor,

Sir,

In his letter in your October number, Mr. Pilkington reads into my paper on mixings the " suggestion that different growths of cotton could be mixed in Egypt with impunity," and that it might lead to the indiscriminate mixing of Egyptian types. This grave misapprehension must be at once cleared up, for the Ministry of Agriculture, of which I have the honour to be a humble servant, is the body in Egypt solely responsible for the vigorous and effective steps taken in recent years to preserve the purity and identity of our varieties.

As the paper published in your *Journal* was addressed to spinners, it was considered unnecessary to deal with the agricultural aspects of the mixing question, but we are nevertheless very much alive to the dangers of mixing varieties in Egypt. Mr. Pilkington's uneasiness will perhaps be dispelled by an extract from the account of these same mixing experiments published in Egypt. This article—a report on the year's work[1]—mentions that we found no nett loss in strength through mixing in the mill and continues as follows:

" On the other hand the tendency for mixing of seed to follow in the tracks " of the practice of lint mixing by growers or ginners is a serious matter, but " its importance is in agriculture, not in cotton-spinning as such. Here the " situation is quite different, for extraordinary plants sometimes arise from " crossings, and the character of the crop might change completely, through " the operation of natural selection. The legislation recently put into opera- " tion restricting mixing of varieties therefore loses nothing of its force, so " far as growers and ginners are concerned."

These views are in agreement with the opinion that any mixing of growths should be done on the individual spinner's responsibility expressed by Mr. Pilkington.

I also agree that it is sometimes impossible to repeat experimental results satisfactorily on a commercial scale ; the fact is only too well known, and my account in the *Journal* was very carefully restricted to a description of our own experiments and the use we ourselves were able to make of the results. But the entire absence of any difficulty met with on the apron drafting system, even when using widely different cottons in the mixings, suggests that insuperable difficulties are not like to arise in commercial use, where the mixing components would usually be less extreme in type. A more difficult question in commercial mixing practice lies in the balancing of the purchasing advantages of a wider choice of cottons against the risk of introducing bars and stripes into the finished goods. All these points are quite beyond the scope of my paper and are more appropriately studied by undertakings with specific requirements in mind.

As regards the value to the spinner of staple regularity in unmixed varieties, distinction must be made between the wastiness of low grade cotton (caused chiefly by insect damage and invariably coupled with other defects), and the normal variation in staple length as found in higher grade cottons. Nobody questions the objection of the former type and it needs no further discussion here[2] ; but after examining the staple diagrams of one or two thousand high grade cottons, we conclude there is not that high association between regularity and yarn quality that we find between staple length or fineness and yarn quality. Such differences in staple regularity as occur are of smaller importance, and are largely masked by other factors. Sea Island cotton is much more irregular than staple fibre, but which makes the better yarn?

Now in deciding the type of seed to issue to growers, a breeder has to weigh up the relative value of the many characters available. Shall he go for high yield, long staple, ginning out-turn, whiteness, resistance to pests, regularity of staple, or what? If he selects primarily for regularity his choice of other characters is restricted ; yield or quality or something else must in part be sacrificed, for no cotton is ideal in all characters. And if, after all, staple regularity is not of the importance he attached to it, then the advantage of his selection is not as great as it might be and in the long run the spinner loses by it. In view of our enquiries, of which the mixing experiment is merely additional confirmation, staple regularity is now considered a factor of secondary importance, but that does not mean it is neglected. Of a much higher order of importance is the wastiness of low grade cotton, which increases the comber waste and is therefore noticed by spinners ; this type is not produced by healthy seeds, and is quite another problem, also under close study.

In reply to the criticism that Maarad was not included in the mixings, it should be noted that Sakha 4 is as long as Maarad, and Giza 26 is even longer, both of which were included ; the samples we selected covered the greatest possible contrast in length.

I would like to add that I do not consider it unreasonable for Mr. Pilkington to have arrived at his conclusions, for it is probable that few people are aware of the measures taken to maintain quality by this Ministry, with its extensive Seed Control Laws and the equally strictly enforced laws prohibiting the mixing of varieties. I am therefore grateful to have his views, and to have this opportunity of reply, which I trust will make the facts clear.

(Signed) F. DUNKERLEY.

Cairo, 11/11/1937.

[1] Studies in Spinning and Growing, 1935-6; Ministry of Agriculture Technical Bulletin No. 189, p.31.

[2] Strength, Price and Grade of Egyptian Cottons, *J. Text. Inst.* 1937, **28**, T183.

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

22—A METHOD OF PRODUCING STANDARD ARTIFICIALLY SOILED WOOL FABRIC

By P. W. CUNLIFFE, Ph.D., F.I.C.
(*late* Wool Industries Research Association.)

INTRODUCTION AND SUMMARY

There is a constant demand for fabrics, soiled in a standard manner, for use in experimental work on laundry processes, the relative detergency of soap and soap-like substances, the influence of alkalis, and other related problems. The uses to which such a fabric may be put are well illustrated by the considerable volume of literature devoted to this subject. A review of work published to 1928 has been given by Rhodes and Brainard.[1] The most generally used method of soiling has been to immerse the fabric—which has usually been a cotton fabric—in a mixture of lamp-black, one or more oils or fats, and benzene or carbon tetrachloride. Numerous methods of standardising the procedure have been given, although most have depended on hand treatment. Other soiling media which have been used are carbon black, carbon and graphite, "Aquadag," "Oildag," benzol soot, ferric oxide, manganese dioxide, Indian ink and pigments, whilst stains have included fruit juice, tea, coffee, etc. The added fatty matter has included lanoline, tallow, mineral oils of various types, olive oil and cottonseed oil.

Morgan[2] (1932) has used a modified form of the soiling medium recommended by the Detergents Committee of the American Oil Chemists' Society. His formula is 2 grams lampblack; 10 grams "Nujol" (a medicinal paraffin oil); 3 grams Russian Tallow and 2 litres carbon tetrachloride. He has constructed a simple machine for soiling, in which an endless piece of cloth, 14ft. by 9ins., passes through a trough containing the soiling medium, through a domestic wringer weighted with a known load, over a series of rollers, and back to the trough. He states that the cloth can be uniformly and reproducibly soiled to a reflectivity of 11·5 per cent., using baryta as the standard.

The method of Rhodes and Brainard and the modifications introduced by Morgan have been used by several workers subsequently (c.f. Snell[3]).

Although the use of fabric soiled in a standard manner is of considerable help in many investigations, it should always be remembered that the soil which is found in actual wear is of a varied nature, so that one type of artificial soil is not likely to represent all the conditions which may occur in practice.

In the present work, preliminary tests showed the need for a constant pressure on the fabric during soiling, in order to obtain level and reproducible results. A description is given of the soiling machine used,

it being a modification of that designed by Morgan. In place of lampblack or other similar black, which has been frequently employed in the past, there is used a crystalline pigment, namely, Ilmenite, which has the advantage that it is obtainable in more definite particle size. It is negatively charged in aqueous suspensions, and its application to cloth in carbon tetrachloride suspensions follows the same lines as that of lampblack.

In soiling in an organic medium, the solvent is lost by evaporation. A new process has been devised, therefore, in which the soil is applied in the form of an aqueous emulsion containing lanoline and paraffin oil, with Ilmenite in suspension. The degree of soiling, as measured by the brightness of the reflected light, can be reproduced in successive batches to within 2 per cent., and the rate of removal of soil on washing is similarly reproducible. When the fabric after soiling is dried at 56°C., the soil is fixed on the fibres rather more tenaciously than when the drying is carried out at room temperature (c.f. Hill[4]). After storage for some months, the soil on the fabric dried at the ordinary temperature becomes more resistant and approaches the fastness of that on the heated fabric, while after 12 months, the two become identical, the heated fabric having become only slightly faster than it was originally. It is recommended, therefore, that drying should be carried out at 50-60°C. in order to prevent any appreciable change in fastness of the soil with prolonged storage.

The knitted fabric soiled in the above manner contains about 3 per cent. of lanoline and paraffin oil, but the greater part of this is removed in the early stages of washing, that is, before all the pigment has been removed.

The rate of cleansing of the soiled knitted fabric, as determined by the brightness measurements, is found to be almost constant over a range of soap concentrations, which includes those normally employed in washing, viz., 0·1 per cent. to 0·4 per cent. soap, in the presence of 0·1 per cent. or less sodium carbonate.

As is well known, the removal of soil by a detergent solution is greatly influenced by the mechanical action to which the fabric is subjected. The original object of the present work was in connection with the standard washing test for the determination of the resistance to shrinkage of wool fabrics. It was hoped that the use of a standard soiled fabric would obviate the need for specifying the type, and the conditions of running of the machine, in which the shrinkage test was carried out. This object was not achieved, there being no satisfactory correlation between the removal of soil and the shrinkage produced in different types of commercial machines. It is thought, however, that the description of the new method of producing artificially soiled fabrics, and of the behaviour of such fabrics on washing and storage, will be of use to others engaged on problems of detergency.

EXPERIMENTAL

Soiling Machine

Preliminary trials were made on the soiling of small pieces of worsted cloth by immersing in the medium in a flat dish, and subjecting to pressure by a hand roller. By these means a fairly uniform soiling could be obtained, but the degree of soiling could not be repeated very accurately.

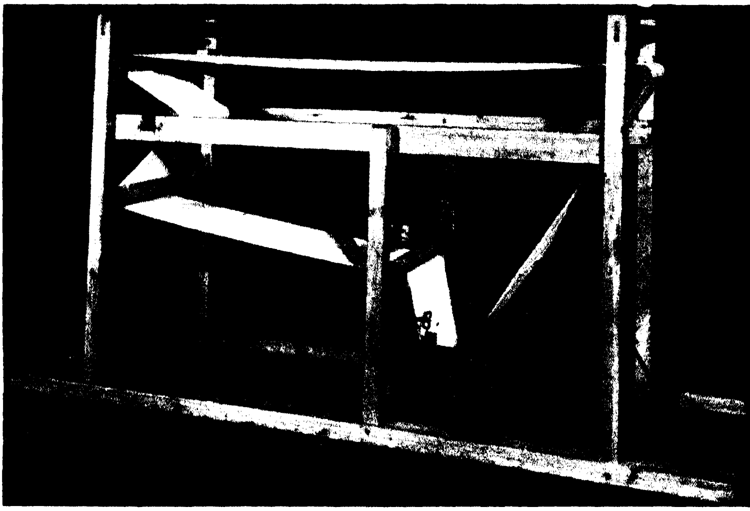


Fig. 1

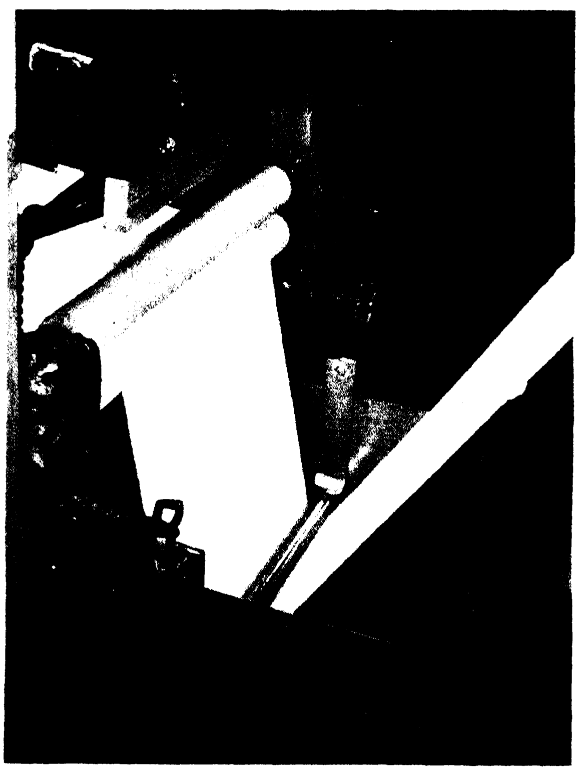
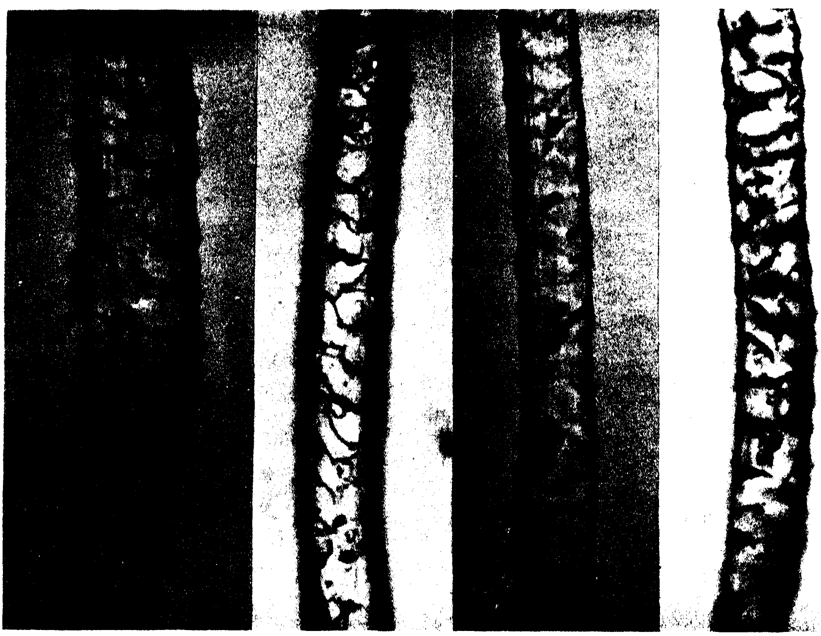


Fig. 2

Facing p. 342



a. b. c. d.

Fig. 3

It seemed apparent that the use of a simple machine would overcome the difficulty, as the cloth could be subjected to a definite pressure, and the soiling process could be prolonged in order to give more level results.

The device which was used, was based on that used by Morgan. It consists of a stout wooden frame, about 6ft. long, 2ft. wide, and 3ft. 6in. high at the ends (Fig. 1). Rubber covered rollers, 16in. long by 2in., support the cloth, three being fixed and one adjustable. Within the framework is fitted a domestic wringer having separate end pressure screws. On the crossbar of the wringer is fixed a simple platform, on which a known weight can be placed, the end screws being left slack so that the pressure on the rollers can be varied in a known manner (Fig. 2). A monel metal trough of semi-circular cross-section is fixed below the wringer, but readily removable, and carries a 1in. stainless steel rod, free to move through about ¼in. vertically, and which serves to carry the cloth below the surface of the soiling medium.

The cloth to be soiled may be 5 to 7 yards long and 12in. or less wide, and is passed through the trough, wringer and rollers, as illustrated. Sufficient slack is given to allow the ends to be sewn together by sliding the adjustable roller to the side.

The wringer is power driven, a convenient peripheral speed being 3in. per sec., which completes one passage of cloth in one minute with a 5-yard length.

In carrying out the soiling operation, the drive is started, the soiling medium is poured quickly into the trough behind the cloth, and a definite number of passages given, depending on the degree of soiling required. When the required depth of soil is obtained, the cloth is cut at the seam when about to enter the trough, with the machine still running, and gathered up; this method eliminates standing of the cloth in the soiling medium.

Soiling Media

The media used in the preliminary work contained lampblack and several grades of carbon black. It was intended to determine the particle size in the blacks used, and to this end the advice was sought of Dr. L. A. Jordan, Director of Research, the Research Association of British Paint, Colour and Varnish Manufacturers. Dr. Jordan pointed out the difficulties of such determinations, and suggested that a more uniform product would be a crystalline black material, such as Ilmenite powder, a titanium ore, obtainable in definite particle sizes. Tests were made on various grades, the one selected finally being "air-floated Ilmenite pigment" of British Titan Products Co., Ltd., Billingham.

The pigment was first applied by the method of Morgan, using a medium of the following composition:—

Lanoline	1·5 grams
Paraffin oil ("Nujol") ...	5 ,,
Ilmenite	5 ,,
Carbon tetrachloride	1 litre

A length of worsted serge, 5 yards by 10in., was soiled in the machine, using 1½ litres of the above medium, 42-lbs. on the top roller, and giving 16 passages occupying about 16 minutes. The cloth before soiling had a brightness of 76 per cent., and after soiling 13 per cent., relative to magnesium carbonate.

This procedure presented no difficulty, but had the disadvantage that the solvent was lost by evaporation. Cheaper solvents were tried, but none was able to keep the Ilmenite in suspension so well as the carbon tetrachloride.

Attention was then given to the production of aqueous emulsions, and no great difficulty was experienced in holding up the Ilmenite, provided that a stabiliser, viz., gelatine, was present. The emulsifying agent used was "Amoa A.1.," manufactured by Messrs. Amoa Chemical Co., Ltd., Grove Park, London, S.E.12. Such an emulsion was used successfully to soil a length of knitted fabric, but the soil was very readily removed on immersing the fabric in soap solution. This difficulty was overcome by treating the dried soiled fabric with a solution of sodium chloride to break the emulsion.

The following section describes the process in detail, the quantities stated being satisfactory for about 5 yards by 10in. of the double-knitted fabric used extensively in the present work.

Emulsion Soiling Process

The soiling medium is prepared immediately before use from the following substances:—

Gelatine	12 grams
Paraffin oil ("Nujol") ...	30 ,,
Lanoline	9 ,,
Amoa A.1	60 ,,
Ilmenite	30 ,,
Water to	3 litres

The gelatine is dissolved in, say, 500 c.c.'s water on a water bath. The Nujol (proprietary brand of paraffin oil) is warmed and the lanoline is stirred in until homogeneous. The emulsifying agent is added, followed by the Ilmenite, and the whole is stirred for 10-15 minutes. To the mixture is then added the hot gelatine solution, and the volume made up to 3 litres with hot water, stirring constantly.

The fabric being in position on the soiling machine, with a weight of, say, 40-lbs. on the roller, the drive is started and the emulsion is poured into the trough behind the fabric. A run of 20 minutes is suitable for soiling to the extent given below.

After the soiled fabric has been dried, it is gently worked in about 10 litres of 2 per cent. sodium chloride solution for 10 minutes, rinsed in water until all the chloride is removed and again dried. (For conditions of drying, see later section.)

Several lengths of knitted web about 3 yards by 12 inches were soiled by the above procedure from an initial brightness of 64 per cent. to 11-12 per cent. The soiled fabric was almost neutral, measurements of diffuse reflection through tri-colour red, green and blue filters, giving 12·8 per cent., 12·3 per cent. and 11·3 per cent. respectively.

A length of cricket flannel was also soiled on the machine, but this, as also the serge soiled by the carbon tetrachloride method, was not considered so good as the knitted fabric. With both these fabrics, the removal of soil proceeded somewhat differently from that found with the knitted, being relatively slower in the early stages and faster in the later stages of washing.

Properties of the Soiled Fabric

A sample of the soiled knitted fabric was extracted with methylated ether and found to contain 3·0 per cent. of mixed oils and fats, the original oil content of the unsoiled fabric being 0·40 per cent. Large test pieces, weighing about 70 grams, which had been washed in commercial machines, were also extracted. It was found that the oils were removed quickly, but the pigment of the soil was retained much more tenaciously. For example, after two washes in a posser type machine, the oil content was 0·82 per cent. and the brightness 31·9 per cent., the original brightness of the soiled fabric being 11·8 per cent. A second sample was washed 4 times in the posser machine, giving an oil content of 0·58 per cent. and a brightness of 53 per cent. It is concluded that the greater part of the oils is removed in a comparatively short time of washing.

Appearance of Soiled Fibres

Photomicrographs of fibres removed from soiled fabrics show that the pigment particles are held on the fibre mainly by the edges of the scales (Fig. 3). Some fibres show a local concentration (Fig. 3a) of particles, such fibres being, no doubt, the outer ones of the fabric. On washing, the particles are gradually removed, leaving a fibre indistinguishable microscopically from the unsoiled.

Washing Tests on Soiled Fabrics. (a) Reproducibility

Two lengths of knitted web were soiled on consecutive days by the emulsion method (laboratory references AS.3 and AS.4) to almost identical values of brightness, drying being carried out at room temperature. Samples of each were given a series of washes in separate containers in an experimental wash wheel, and the brightness measured after each wash. The wash consisted of 0·2 per cent. sodium oleate and 0·1 per cent. sodium carbonate; ratio of liquor to sample was 12:1; temperature 35°C., and two liquors were given for 10 and 6 minutes, respectively, followed by 3 rinses of 2 minutes each.

Table I. Washing of Soiled Knitted Fabrics

No. of Washes	Brightness	
	AS.3	AS.4
	%	%
0	11·1	12·1
1	26·6	23·9
2	43·9	39·1
3	46·7	45·0
4	45·7	48·4
5	51·1	47·8
6	53·6	50·2

After an interval of three months, another length of web was soiled (laboratory reference AS.5), but this was dried over heated rollers at about 56°C., the fabric being kept in motion.

The following values were obtained in a series of washes on the soiled fabrics AS.4 and AS.5.

The soil on Fabric AS.5 is slightly more resistant than on AS.4. The conditions of these washes were not quite the same as those detailed in Table I, but it would appear that the soil has become rather more firmly fixed on fabric AS.4, during the interval of 3 months.

Table II. Washing of Soiled Knitted Fabrics

No. of Washes	Brightness	
	AS.4	AS.5
	%	%
0	12·1	11·4
1	27·5	24·7
2	33·9	29·5
3	37·9	30·6
4	40·6	34·8
5	42·6	36·6

After an interval of 12 months from the date of soiling of the AS.3 and AS.4 fabrics, a series of 10 washes was carried out on the AS.4 and AS.5 fabrics, by each of two processes. Both processes were with 0·2 per cent. sodium oleate and 0·1 per cent. sodium carbonate, but whereas the first was a very mild wash, the second was made more severe by including 6 steel balls with each sample. The following values of brightness were obtained:

Table III. Comparison of Rates of Removal of Soil

No. of Washes	Mild Wash		Severe Wash	
	AS.4	AS.5	AS.4	AS.5
	%	%	%	%
0	11·6	12·5	11·7	12·5
1	18·3	19·6	21·1	22·2
2	20·3	21·7	25·7	26·6
3	22·4	23·5	27·5	29·4
4	24·2	25·0	31·6	31·9
5	24·9	26·3	34·7	35·7
6	26·4	27·7	36·1	38·8
7	28·3	29·4	39·5	40·2
8	28·7	31·2	41·1	42·1
9	30·7	31·5	41·3	42·9
10	31·4	33·1	44·6	45·2

The agreement between the two fabrics is good. The conditions of the " severe wash " in this test were identical with those of Table II; comparison of the brightness values in the two tables shows that the soil of fabric AS.5 is only slightly more resistant after the period of storing. Fabric AS.4, however, has become appreciably more resistant. In using the soiled fabric dried at room temperature, it is thus necessary to employ freshly soiled material, or alternatively to carry out a control test under standard conditions each time the fabric is used. From this point of view there is advantage in using the heat treatment for drying the soiled fabric, as once the soil is so fixed very little further change takes place. It is essential, however, to control the heat carefully as higher temperatures, e.g., 120°C., fix the soil very firmly. As previously stated, the fabric AS.5 was dried at 56°C., and lacking further investigation, this should be regarded as a suitable temperature.

(b) Influence of Soap and Soda Concentration on Detergent Action

In the work of Rhodes and Brainard,[1] it was shown that only a slight increase in detergent efficiency is obtained by increasing the soap concentration above 0·1 per cent. Morgan,[2] on the other hand, found a definite increase in efficiency until a maximum is reached at 0·25 per

cent. In the present work, a series of washes in the wash wheel with different concentrations of soap and soda gave the following increases in the value of brightness over that of the unwashed fabric, the soap being sodium oleate and the alkali sodium carbonate.

Table IV

Wash Liquor.	Brightness Increase
0·1% soap + 0·1% alkali	... ... 30·7%
0·2% soap + 0·1% alkali	... ... 31·9%
0·4% soap + 0·1% alkali	... ... 31·9%

The detergent efficiency does not vary appreciably over this range of soap concentrations.

These results were checked by a series of washes in a 24 by 36in. rotary machine, kindly carried out by a co-operating firm, Table V showing the increases in brightness obtained.

Table V. Influence of Soap Concentration on Detergency

Wash Liquor	Number of Washes					
	1	2	3	4	5	10
Water only (i)	1	3	6	6	7	9
Water only (ii)	2	3	4	4	5	—
0·15% soap + 0·04% alkali (i)	12	23	27	27	27	31
0·15% soap + 0·04% alkali (ii)	12	18	20	23	25	—
0·1% soap + 0·1% alkali	13	20	25	29	31	32
0·4% soap + 0·1% alkali	14	19	23	26	28	28

It may be noted that the increase in brightness obtained in the laboratory tests (Table IV) is almost identical with that obtained in 10 washes in the rotary machine (Table V).

The increases in brightness obtained in the rotary machine are not so regular as those found with the wash wheel, but allowing for the difficulties of giving uniform treatment to a sample forming but a small proportion of the total load, it is concluded that over the range of soap concentrations investigated, the rate of removal of soil is constant.

(c) Influence of Mechanical Action

It was hoped that the soiled fabric could be used as a means of calibrating commercial laundry machines in an investigation designed to set up a standard method for testing the resistance to shrinkage of wool fabrics. It was realised that the different types of machine subject the goods to different degrees of mechanical action. If, however, a time of treatment for each machine could be given, such that a piece of standard soiled fabric increased in brightness by a given amount, the peculiarities of the machine would be eliminated.

The influence of mechanical action on the rate of removal of soil and its relation to shrinkage was investigated on the wash wheel. Two identical samples of unsoiled knitted fabric, which had received no treatment other than scouring, were washed at the same time and with the same amount of soap and soda, but in different vessels. In one of the vessels, six stainless steel balls, ¾in. in diameter, were added, in order to increase the mechanical action. In the other, no addition was made. A small sample of the soiled fabric AS.5 was included in each test. After

2½ hours, the shrinkages in area were 6·1 per cent. without steel balls and 28·4 per cent. with steel balls, while the increases in brightness of the soiled samples were 15·2 per cent. and 30·2 per cent., respectively. This and other similar results indicated that it might be possible to use the standard soiled fabric in the desired manner, although there was no simple relation between the rate of shrinkage and the rate of increase in brightness.

When similar tests were carried out in five commercial laundry machines of three different types, it was found that a given increase in brightness was accompanied by widely differing amounts of shrinkage. It was concluded, therefore, that the soiled fabric could not be used to standardise the commercial machines. Nevertheless, there would appear in this connection to be a use for the soiled fabric when a particular machine is under investigation with the object of establishing the conditions under which minimum shrinkage may be obtained consistent with reasonable cleansing.

REFERENCES

[1] Rhodes and Brainard. *Ind. Eng. Chem.*, 1929, **21**, 60-68.
[2] Morgan. *Canadian J. Research*, 1932, **6**, 292-305.
[3] Snell. *Ind. Eng. Chem.*, 1933, **25**, 1240.
[4] Hill. *J. Agric. Res.*, 1929, **39**, 539.

Received 11/8/37.

23—METHODS FOR THE ESTIMATION OF MEDULLATION IN WOOL SAMPLES

By P. R. McMahon, M. Agr. Sc. (N.Z.)., Ph.D. (Leeds).

(Massey Agricultural College, New Zealand)

INTRODUCTION

The requirements of the manufacturer in regard to freedom from medullated fibre (hairiness) in wools destined for use in standard fabrics in both the woollen and worsted trades have been widely discussed at various times from the viewpoints of both the consumer and the producer of the raw material. Unfortunately, up to the present time, no satisfactory method for the quantitative expression of the defect has been available, and while it is well known that coarse medullation has an effect on the value and potential uses of wool, exact research into the problem has not been possible owing to the lack of a means of measurement. Medullation can be detected by hand and eye only when it exceeds a certain coarseness, and the effects of fine medullation on the behaviour of material during processing and in wear seem to be entirely unknown; it seems reasonable to expect that the exact expression of this defect may have an important bearing on the problem of "quality" specification. Further, from the animal husbandry aspect, consideration of wool and carcase quality as both contributing to the breeding value of an animal make essential a finer discrimination than can be achieved by traditional methods if economic wool improvement is to be realised.

The "Benzol" Test

Studies of medullation undertaken in New Zealand made apparent the need for an accurate and rapid technique capable of giving a numerical index to the medullation of a sample of wool, and the "Benzol" test was introduced by Elphick (1932). In this test a small staple of wool is cleansed in petrol, teased out into a thin film of fibres and immersed in benzene in a flat dish over a black background. Medullated fibres stand out white and chalky while pure wool becomes almost invisible. The quantitative application of the test proved difficult; discussing the evaluation of the medullation revealed, Elphick has pointed out that there are four factors which must be taken into consideration in an estimation of the percentage volume of medulla, which he regarded as the ideal index:

(1) The percentage of fibres medullated.
(2) The average distance down the fibres which medullation extends.
(3) The average diameter or coarseness of the medullation.
(4) The average diameter of the fibres in the sample.

In order to arrive at an empirical index, he estimated the first two of these visually, calculated the percentage of medullated fibre in the staple, and weighted the result arbitrarily according to the type or grossness of the medulla. Effects of variation in fibre diameter were small compared with the total range of values and were neglected. Thus a sample considered to contain 50 per cent. of its fibres medullated for a distance of half their length was scored as $50 \times \frac{1}{2} \times 3 = 75/300$ if the medullation was

" coarse ", as $50 \times \frac{1}{2} \times 2 = 50/300$ if the medullation was " medium ", or as $50 \times \frac{1}{2} \times 1 = 25/300$ if the medullation was " fine ".

After using the method in work on fleece mapping, Elphick came to the conclusion that while it was the best means then available for classifying the large number of staples under examination, it could not be regarded as satisfactory owing to the personal element involved, especially as the method of weighting the result on the basis of medulla diameter masked the comparatively accurate estimation which could be made of the first two factors. It was recognised, also, that the method used was purely empirical, and Elphick proposed to relate the figures to the percentage volume of medulla determined by some absolute means. Preliminary investigations on the determination of the specific gravity of the wool samples had been commenced when unforeseen circumstances brought the work to a standstill.

EXPERIMENTAL

The Evaluation of Medullation. —1. Visual Estimation in Benzene. The Percentage Volume of Medulla

At the commencement of the present work, a number of estimations were made using Elphick's technique, but repeats on the same samples, even after quite short intervals, shewed that considerably more experience than that gained by the testing of a few hundred samples would be necessary before any degree of reliability could be achieved. In an analysis of the sources of error, it was found that different persons using the same samples varied very considerably in their estimations of the percentage of fibres medullated, while microscopic counts of samples carefully examined by Elphick shewed that even with an experienced observer the percentages estimated did not necessarily coincide with the microscopic values. It was obvious, too, that unaided visual estimation of the percentage of medullated fibres was affected by medulla diameter to a much greater extent than had been expected. Finally, it seems that the estimation of the coarseness of the medulla, which Elphick points out can only be divided into four groups visually, must be the limiting factor in evaluation by this method, even assuming reasonably fine discrimination in the case of the first two factors and an accurate estimation of fibre diameter.

The Evaluation of Medullation.—1. Visual Estimation in Benzene. The Percentage Total Fibre Length affected by Medullation

While not of such a fundamental nature as the percentage volume of medulla, the percentage of the total fibre length in the sample affected by medullation offers a sound basis for estimation and selection of animals for breeding purposes. As a temporary measure a method for its visual estimation was developed, the figures being supplemented with a brief description of the type and distribution of the medullation. A photographic standard was prepared having narrow zones shewing the appearance in benzene of various percentages of medullated fibre at a standard degree of teasing of 300 fibres to the inch. Samples teased to this thickness, which could be readily reproduced to within 5 per cent., were immersed in benzene and estimations of percentage medullation were made by comparison with the standard at intervals equally spaced down the staple. For routine work seven estimations were made on each staple, corresponding to one inch intervals on the average Romney staple

of about seven inches. Results obtained by this method were found to be in good agreement with checks made by direct counting, and it was found that provided attention was concentrated on the average distance between adjacent medullated fibres when making comparisons, variation in medulla diameter did not affect the accuracy of the result.

The method proved slow in routine use and modifications have been made by other workers at this college, but it is not known how completely the effect of medulla coarseness on the estimation of percentage has been eliminated in the amended technique. While the simplicity of this visual method was a very strong recommendation, making it available to the individual sheep breeder without modification, the fact that accuracy could be obtained only with considerable sacrifice of speed of working made the exploration of other possibilities desirable.

The Evaluation of Medullation.—2. Estimation by Optical Methods

Since hair reflects considerably more light than pure wool when in benzene, an integration of the amount of light reflected, i.e., the apparent whiteness of the sample, might be expected to serve as an index of the degree of medullation. At first sight it might appear probable that this amount of light would be a function of the surface area of the medullae, in which case a linear relation between light reflected and percentage volume of medulla would not obtain. Thus a given amount of fine medulla would have a greater surface area, and hence reflect more light, than the same amount of coarse medulla. There are, however, such a large number of factors affecting the issue, that one cannot regard such a relation as being established on *a priori* grounds. The effect of the internal structure of the medulla upon its apparent whiteness, the distorting effect on apparent diameter due to the cortex of the fibre acting as a lens, reflection from the ends of small sections when the medulla is discontinuous, and probably many other factors, would all require careful evaluation. Actually, however, a linear relationship has been established between measurements of light reflected and the percentage *volume* of medulla calculated from specific gravity measurements. (See Table V.)

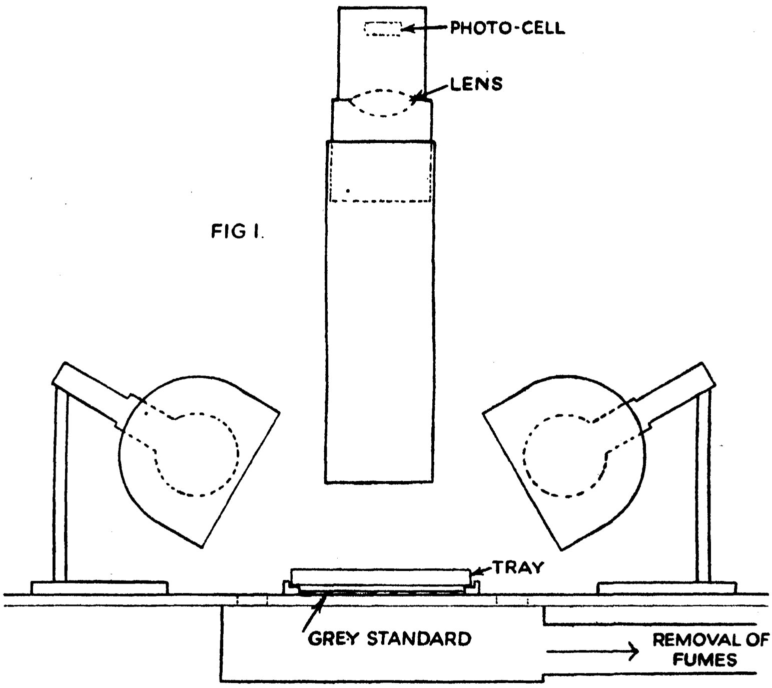
Preliminary Experiments

A first attempt was made to measure the amount of light reflected from a moderately hairy sample in benzene, when placed in the beam from a projection lantern, with a Lumner-Brodhun cube, but the intensity of illumination was too low for the instrument to be applied successfully. Further experiments were next made by means of a photo cell of the " blocking layer " type (Weston, " Photronic "), and the results indicated that if used in conjunction with a suitable registering instrument, it would be capable of measuring the light reflected from the wool with considerable accuracy. A constant source of illumination, capable of producing an evenly distributed luminous flux over the tray, was essential if a given amount of medulla were to give a constant reading without reference to its position in the tray.

During the development of the photo-electric apparatus, such difficulty was experienced in obtaining uniform illumination of the tray surface, while at the same time maintaining sufficient intensity to give the required sensitivity, that attempts were made to measure the amount of light *absorbed* by the medullated fibres. It was concluded, however, that any

method relying on the measurement of light absorbed by the medullation, while at the same time retaining the physical condition of the sample necessary for its visual description, could not give satisfactory results. In the case of experiments with transmitted light, the variations in light flux falling on the photometric surface, due to fluctuations in the source arising from line voltage variations, are superimposed on the variations due to the actual absorption. In the case of measurement of light reflected by the medullation, on the other hand, the fluctuations bear a constant ratio to the quantity being measured, since the light reflected by the tray filled with benzene is almost negligible. Thus in the former arrangement the ratio of the changes due to absorption to the other sources of variation in the quantity measured is not sufficiently high; the possibility of error being between 5 and 10 per cent. of the actual absorption.

FIG I.



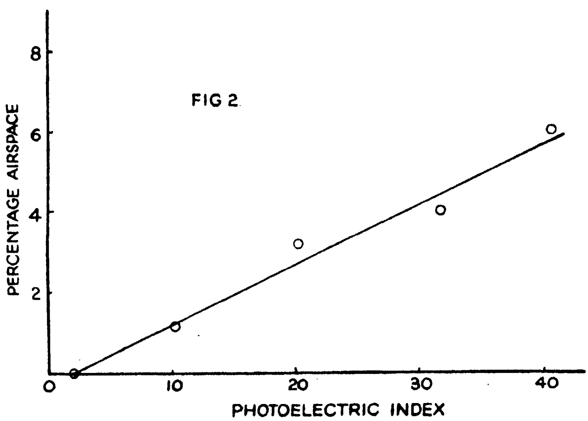
The Final Apparatus.

(*a*) *General.* The form taken by the final apparatus is illustrated in Plate I and shewn diagrammatically in Fig. I. It will be seen that the instrument consists essentially of a system of lighting which illuminates the wool, lying immersed in benzene, and a simple optical arrangement by means of which an image of the illuminated sample is produced on the light sensitive surface of a photo-cell. A direct reading is obtained on the galvanometer scale, the instrument being standardised between readings by means of a grey enamel plate. The latter lies directly under the tray, and is exposed to the lamps and cell when the tray is withdrawn for the purpose of changing the sample.

(*b*) *The lighting system.* Difficulty experienced in obtaining intense yet even illumination, due to the action of the inverse square law, was obviated by resort to light sources having large emitting area relative to

their distance from the surface to be illuminated. Supplemented by suitable matt surface reflectors, four 200-Watt Phillips' "Argenta" lamps were found to give the desired conditions. With the present arrangement fine control of line voltage was not essential, and manual control by means of a rheostat and voltmeter were found satisfactory. An attempt to use ballast lamps for the stabilisation of power supply proved unsuccessful.

(*c*) *The tray*. Some difficulty was experienced in obtaining a suitable background for the wool in the tray, fulfilling the requirements of blackness and permanence under routine conditions. The angle of illumination being necessarily low, a dead black surface was not suitable owing to the high diffuse reflection produced. In practice a slab of "flashed black on opal" glass was found to be the most satisfactory medium, especially



as it allowed a convenient means of marking out the area actually scanned by the cell by drilling through the black surface until a small dot of opal was visible.

(*d*) *The benzene*. The refractive index of the benzene used was not found to be extremely critical, and the manufacturers found no difficulty in supplying a product with refractive index between the permissible limits of 1·490 and 1·495 (20°C.) (Table I).

Table I. Effect of variations in refractive index of benzene on photo-electric index

Refractive Index 20° C.		1·4797	1·4900	1·4952	1·5000
Sample	Weight	Photo-electric Index			
	gr.	cm./gr.	cm./gr.	cm./gr.	cm./gr.
Pure wool	0·520	3·2	2·4	1·8	1·4
Few hairs	0·465	5·0	3·9	3·4	3·4
Hairy tip	0·555	5·7	4·3	3·6	3·0
Hair throughout	0·475	56·0	52·5	51·2	52·5

(*e*) *The optical system*. This consists of a velvet-lined box, supported at an adjustable height above the tray surface and having a telescoping section, which supports the lens and cell. Various combinations of lenses were tried, a Bausch and Lomb projection condenser (PM 25, diameter 5¼ inches, focal length 4 inches) being found to be the most suitable of those economically practicable. Fortunately, since the measurements were concerned with the total light quantity, extreme perfection of the image

was not essential although a certain degree of definition was necessary in order to permit limitation, by means of a mask on the cell surface, of the area of the tray actually scanned.

(*f*) *The photo-cell and galvanometer.* The photo-cell used is a Weston " Photronic " of high sensitivity, suitably supported in a black-lined, light-tight compartment immediately over the lens. The galvanometer is a standard Cambridge instrument, suitable resistors being incorporated into the circuit for the control of sensitivity and damping.

(*g*) *Adjustment and empirical standardisation.* After focussing an image of the required portion of the tray on to the cell surface, the galvanometer is switched in and, with the aid of a bright object of suitable size, the angle and position of the lamps, reflectors, and the lower edge of the box supporting the lens, are all varied until the deflection of the galvanometer is independent of the position of the object in the tray. The lamp voltage is now fixed at a convenient value (220 volts) and the galvanometer scale brought to zero reading when the tray, containing benzene and the glass plate used to hold the wool samples in position, is exposed to the cell. The tray is then withdrawn, exposing the grey standard surface, and the sensitivity of the galvanometer adjusted to give a certain fixed deflection (20 cm.). Finally, as a reference standard, a grey enamel plaque is placed *in* the benzene, occupying the exact position of the wool samples, the deflection obtained bearing a definite ratio to the value set for the sub-tray standard if all the foregoing adjustments have been correctly made. In practice, the actual sensitivity level was arbitrarily fixed by sorting a quantity of coarse kempy fibres and adjusting to give a photo-electric index of 100 cm./gr. for such material. Regarding this sample as 100 per cent. coarse hair, it thus becomes convenient to refer to subsequent values as " medullation equivalent to *n* per cent. coarse kemp ".

Owing to the phenomenon of infilling described by Elphick (1932), wool samples do not accurately retain a given degree of medullation for an indefinite time. Table II gives data for certain samples re-examined after storage over $CaCl_2$ for five months, and gives some idea of the irregular nature of the changes due to infilling of the medulla, even under conditions regarded by workers at this college as being the optimum for stability. Attention was, therefore, devoted to the possibility of obtaining an easily reproducible means of standardising the sensitivity of the instrument, but no suitable substance was found. A compromise was effected by the use of the grey enamel plaque calibrated by comparison with wools having known degrees of medullation determined by specific gravity measurements described later in the paper.

(*h*) *Method of experiment.* In brief, the routine of examination is as follows: Sub-samples of approximately 0·4 grams are rinsed in petrol to remove grease and dirt, teased to a roughly constant thickness (see Table III), and allowed to stand for a short time in order that traces of petrol may evaporate. The samples are now submerged in the benzene with a glass plate, care being taken to avoid air bubbles, and a visual examination is made, simple abbrevations being used to record the occurrence and distribution of medullation over the staple. Should there be no medullation present, no further measurements need be made on the sample. In the case of medullated samples, after checking the deflection

Table II. Changes in degree of medullation in wool samples stored over calcium chloride for five months

Sample	Photo-electric Index	
	April, 1935.	August, 1935
	cm./gr.	cm./gr.
1	2·1	2·2
2	2·7	2·2
3	4·3	3·9
4	6·3	5·5
5	8·1	6·8
6	9·6	9·0
7	10·1	8·4
9	13·8	10·5
10	15·3	14·6
11	19·0	12·2

Table III. Effect of variations in thickness of spreading on photo-electric index

Sample	Treatment	Weight	Photo-electric Index
		gr.	cm./gr.
A.—Pure wool	Average spreading	0·715	1·6
	Folded to cover half usual area	...	1·8
B.—Hairy tip	Average spreading	0·555	3·9
	Folded to cover half usual area	...	4·3
	Folded to cover quarter usual area	...	4·7
	Opened to original area ...	...	3·9
C.—Hairy	Average spreading	0·270	38·5
	Opened to one and a half usual area	...	37·5
	Folded to quarter usual area ...	...	39·4

from the sub-tray standard, the operator places the tray in position under the lamps and optical apparatus, the steady galvanometer reading being recorded after a few seconds. Tray and sample are now withdrawn, and the deflection from the grey standard again checked in preparation for the next staple. Following examination in benzene, the samples are allowed to dry and condition in the atmosphere of the laboratory prior to weighing. Although facilities have not been available for more accurate control of moisture content of the samples, the local atmospheric conditions are such that only under very extreme conditions could an error greater than 5 per cent. arise; moreover, this error would only be appreciable in the strongly medullated samples where extreme accuracy is not essential. It is hoped that suitable controlled humidity storage space will become accessible in the future. For the weighing, a Bunge damped balance was adapted to work with a 5 decigram rider, and the weights recorded to the nearest 5 milligram (1 per cent.).

From the point of view of time required to complete an estimation, the photometric method has proved particularly satisfactory, a necessity in such routine determinations where the value of the work is dependent upon the ability of the organisation economically to handle a large number of samples. The present technique has proved more rapid in practice than visual methods previously in use, due largely to the smaller degree of care necessary in obtaining a constant degree of teasing, and to the rapid despatch of pure wool samples, which may be classed visually.

In routine work at the Massey College, a staff of four has been found adequate for the testing of over 400 samples per day, equivalent to some 60 sheep.

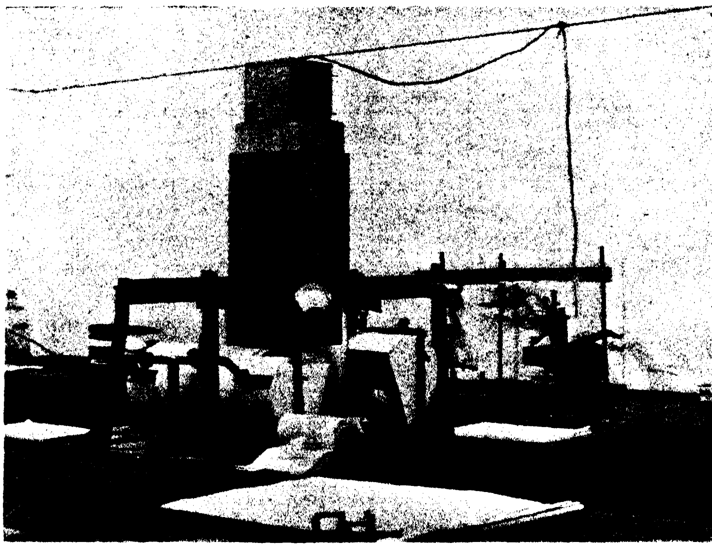


Plate I

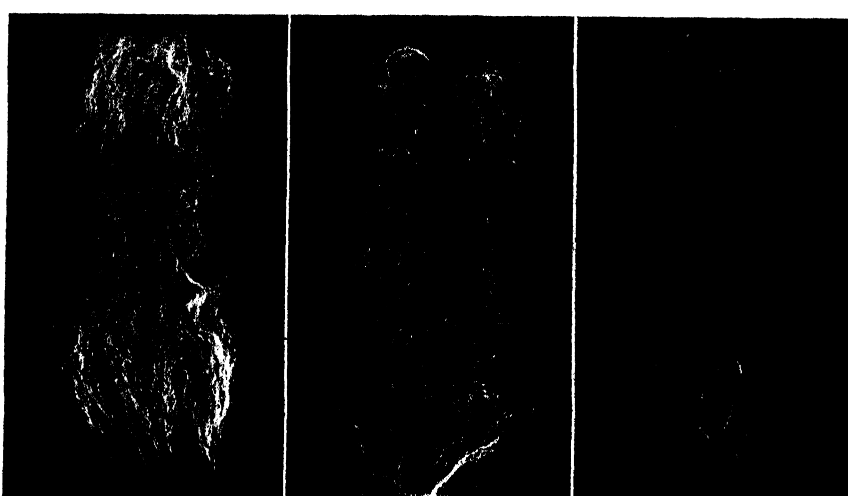


Plate II. Romney Wool Staples in benzene (× 1/3)
A. 3·8 cm./gr. B. 18·0 cm./gr. C. 54·9 cm./gr.
(NOTE: The degree of photographic contrast necessary for satisfactory reproduction of these illustrations has increased the apparent medullation of the samples.)

(*i*) *Results*. As a basis of comparison between samples, the deflection per gram of wool, termed the photo-electric index of medullation, has been found satisfactory. For routine calculation of this figure a slide rule was found more rapid and less subject to error than either nomographic

or tabular methods. Typical results are shewn in Table IV, some of the samples being shewn in Plate II. The approximate range of values encountered in practice lies between a deflection per gram of 2.0 cm. for pure wool samples and of the order of 50 cm. for very hairy material. An indication of the degree of reproducibility of results under routine conditions is also shewn in Table IV. These samples are typical of a series which was examined and then used for demonstration purposes. standing exposed in trays on the laboratory bench away from direct sunlight for a period of some three weeks before re-examination. Variation in the case of sample 3 is due to infilling.

Table IV. Typical results and reproducibility after three weeks' interval

Sample	Series *a*			Series *b*		
	Weight	Deflection	Photo-electric Index	Weight	Deflection	Photo-electric Index
	gr.	cm.	cm./gr.	gr.	cm.	cm./gr.
1	0·410	1·1	2·8	0·415	1·0	2·4
2	0·390	1·5	3·8	0·390	1·4	3·6
3	0·275	2·0	7·3	0·275	1·5	5·5
4	0·300	5·4	18·0	0·295	5·2	17·6
5	0·190	7·4	39·0	0·190	7·4	39·0
6	0·295	16·2	54·9	0·295	16·5	55·9

The Evaluation of Medullation.—3. Estimation by Specific Gravity Determination

As explained above, the light reflected from a sample of wool in benzene can only be an empirical index of medullation, and following Elphick's lead, the possibility of determining the specific gravity of wool in a liquid not absorbed by the fibre has been investigated. If King (1926) is correct in maintaining that the density of medulla-free wool is constant, regardless of origin, then a simple calculation gives the percentage air-space in the fibre, and hence a reasonable index of the degree of medullation.

It was at first considered that the results would be of the greatest value if the comparisons were made over the range of photo-electric indices most important in practice, i.e., 2.0—10.0 cm./gr., where, moreover, error due to penetration of the density liquid into coarse medullae would be small. Accordingly, considerable time was spent in the development of a technique sufficiently precise to give reliable differences within these limits. Approximate computation shewed that the accuracy required would be of the order of 0.1 per cent.

Technique of specific gravity determination

The samples were cleansed in three changes, each of 15 minutes, of benzene and distilled water at 45° and 55° C., respectively, according to the method advocated by Roberts (1930), save that no saponin was added to any of the distilled water washes. After a preliminary drying, the samples were transferred to specific gravity bottles and dried at 105° C. to constant weight, a slow current of dry air, also at 105° C., being blown through the wool. No difficulty was experienced in achieving constant weight to within 0.1 milligram on a 2 gram sample.

The determinations were made in a specially selected specific gravity bottle (50 c.c.), to the neck of which was fitted a carefully ground glass cap

to prevent loss of benzene by evaporation during weighing. The volume of the bottle was determined in the usual way, and was found to remain constant during the course of the experiments to within 3 parts in 500,000.

"Pure, Crystallizable" benzene, dried over calcium chloride, was used as the density liquid, and was introduced slowly into the specific gravity bottle, containing the dry wool, in an atmosphere freed from water vapour. The purpose of these estimations being the determination of the amount of air-space actually contained in the fibre, removal of air adhering to the fibres externally by the usual process of boiling under reduced pressure was not possible. In actual practice, the tendency to retain air was found to be considerably reduced by loose packing of the wool in the bottle, and it was possible to remove any traces of gas by means of a long hypodermic syringe. This simple method was found to be entirely satisfactory, as even the smallest bubbles were visible on account of the curvature of the vessel.

An important feature observed throughout the investigation was the standardization of the force used in inserting the stopper of the bottle, a spring balance being utilized to secure uniformity.

All determinations were made at a temperature of 25° C. on a standardized Beckmann thermometer, 60 minutes being allowed for the equilibration of the temperatures of bath and bottle contents.

Errors in weighing due to irregular condensation of a film of moisture on the outer surfaces of the glass vessel were eliminated by the use of a glass counterpoise. All weights were calculated to weight in vacuo, allowance being made for the effect of variations in temperature and barometric pressure on the density of the air in the balance case at the time of weighing.

Results.

With these precautions it was found possible to reduce the error of the estimation to approximately 0·05 per cent. On applying these methods to wool free from medulla, it was found that the specific gravity of wool samples from three different Romney fleeces varied significantly from fleece to fleece from 1·300 to 1·296 gr./c.c. 25°/4°, the higher values being associated with high medullation in other portions of the fleece. In view of this result attempts to secure an exact and detailed determination of the relation between the percentage air-space and the photo-electric index over a range of low medullation values was abandoned and a series of determinations made to give a more approximate standardization over a greater range, 2·0 to 40 cm./gr. Estimations of percentage air-space from these results are shewn together with the average photo-electric index of the wool in Table V (Fig. 2). These former figures were calculated from the formula:

$$\text{Air-space} = 100(D_k - D_m)/D_k$$

where D_k is the specific gravity of pure keratin, assumed constant at a value of 1·3008 gr./c.c., 25°/4°, and D_m is the specific gravity of the medullated sample.

Owing to the errors involved in the assumption of a constant value for D_k in the above equation, and a further uncontrollable error which would arise in determinations of coarse medullation due to penetration of the density liquid into the medullae, great accuracy cannot be claimed for the calculated percentages of air-space. In view of these considerations,

deviations from the linear relationship between the photo-electric index and calculated air-space cannot be regarded as due to fundamental shortcomings of the optical method. The realisation of an approximately linear relation between the quantities measured indicates that the light reflected from medullated wool in benzene is more closely related to the volume than to the surface area of the medullae, owing to the complications discussed earlier in the paper.

Table V. Relation of photo-electric index to percentage air space in medullated samples

Sample		Specific Gravity 25°/4° C.	Percentage Air space	Photo-electric Index
				cm./gr.
1	Pure wool	1·3008	0·00	2·1
2	Hair throughout	1·2860	1·14	10·4
3	,, ,, ...	1·2593	3·19	20·4
4	,, ,, ...	1·2492	3·97	31·9
5	,, ,, ...	1·2230	5·99	40·6

PRACTICAL APPLICATIONS

The fact that the photo-electric method can distinguish and measure finer grades of difference in degree of medullation than the human eye is capable of recognising, combined with its advantageous speed of working, has enabled the instrument to become the basis of a scheme of large scale flock testing. In the twelve months ending 30th November, 1935, a total of 8,599 registered sheep had been examined by the organisation, and at that time a further 6,680 were already booked for future testing. (Waters, 1936). It is hoped to give details of the sampling and grading methods adopted in a later communication. In addition to the information supplied to the breeder, many valuable data are accumulating relating to the development and distribution of medullation in the fleece and the inter-relation of genetic and environmental influences. Further extension of the activities of the organisation to include measurement and recording of other important fleece characters is taking place as rapidly as facilities permit.

It is important to note that whilst the instrument described in the present paper was originally designed for use with fleece wool, it has been found quite suitable for the examination of tops without any further modification.

SUMMARY

Elphick's visual method for the evaluation of medullation revealed by the "Benzol" test has been shewn to possess certain inherent failings, and a more accurate technique developed on a visual basis proved too slow for routine application.

A photo-electric apparatus has been constructed which is capable of measuring degrees of medullation rapidly and with considerable accuracy. An approximately linear relation has been found between the index so obtained, and the percentage air-space in the fibre calculated from accurate specific gravity determinations in benzene.

The apparatus has proved satisfactory under routine conditions, and has been used on an economic basis by an official fleece testing organisation in New Zealand during the past two years.

ACKNOWLEDGMENTS

My best thanks are due to the Physics Department of Victoria University College, Wellington, N.Z., for the loan of apparatus, and in particular to Mr. G. A. Peddie, without whose advice and assistance this work could not have been initiated. I wish also to thank the Principal and members of the Staff of Massey Agricultural College and the Dairy Research Institute for helpful criticism and opportunities for discussion of sundry problems. Finally, I wish to express my indebtedness to Dr. J. B. Speakman of The Textile Department, Leeds University, who kindly provided facilities for some of the specific gravity determinations, and has given much valuable criticism during the preparation of this paper.

Certain of the photo-electric indices quoted were carefully determined by Miss D. Cleary.

The latter part of this work was carried out with the aid of a grant from the Farmers' Union Scholarship Fund.

REFERENCES

Elphick (1932). *J. Text. Inst.*, **23**, T367.
King (1926). *J. Text Inst.*, **17**, T53.
Roberts (1930). *J. Text. Inst.*, **21**, T127.
Waters (1936). First Annual Report of the Fleece-Testing Department, *Massey Agricultural College Bull.*, No. 4.

Received 24/8/37

THE

Journal of the Textile Institute

VOL. XXVIII—1937

TRANSACTIONS—NAME INDEX

Date of Issue	Date of Issue	Date of Issue

GIPNLK--33 IARI 61-- 10-6-63 -- 4,000